

AD-764 732

VULNERABILITY OF DRY BAYS ADJACENT TO  
FUEL TANKS UNDER HORIZONTAL GUNFIRE

Robert G. Clodfelter

Air Force Aero Propulsion Laboratory  
Wright-Patterson Air Force Base, Ohio

March 1973

DISTRIBUTED BY:



National Technical Information Service  
U. S. DEPARTMENT OF COMMERCE  
5285 Port Royal Road, Springfield Va. 22151

AFAPL-TR-72-83

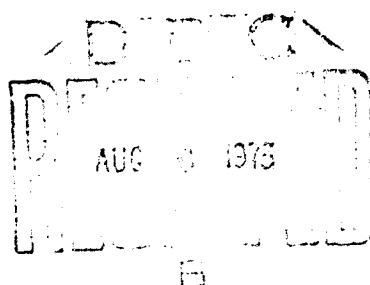
AD 764732

## VULNERABILITY OF DRY BAYS ADJACENT TO FUEL TANKS UNDER HORIZONTAL GUNFIRE

ROBERT G. CLODFELTER

TECHNICAL REPORT AFAPL-TR-72-83

MARCH 1973



Approved for public release; distribution unlimited.

Report prepared by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
U.S. Department of Commerce  
Washington, D.C. 20472

AIR FORCE AERO PROPULSION LABORATORY  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

## NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any right or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

RECORDED IN	
RTIS	State Section <input checked="" type="checkbox"/>
DC	Can. Section <input type="checkbox"/>
LC	<input type="checkbox"/>
BY	
DRAFTED BY: [Signature]	
DATE: [Signature]	
DRAFTED FOR: [Signature] OFFICIAL	
A	

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Aero Propulsion Laboratory Wright-Patterson Air Force Base, OH 45433	2A. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
2B. GROUP	

3. REPORT TITLE

VULNERABILITY OF DRY BAYS ADJACENT TO FUEL TANKS UNDER HORIZONTAL GUNFIRE

4. DESCRIPTIVE NOTES (Type of report and Inclusive date)

March 1966 through June 1971

5. AUTHOR(S) (First name, middle initial, last name)

Robert G. Clodfelter

6. REPORT DATE March 1973	7A. TOTAL NO. OF PAGES 703 101	7B. NO. OF REFS 3
8. CONTRACT OR GRANT NO.	8A. ORIGINATOR'S REPORT NUMBER(S)	
9. PROJECT NO. 3048	AFAPL-TA-74-23	
c. Task Nr. 304807	9B. OTHER REFFORWING (Any other numbers that may be assigned this report)	
d.		

10. D. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING & LITARY ACTIVITY Air Force Aero Propulsion Laboratory Wright Patterson Air Force Base, OH 45433
13. ABSTRACT	

This report deals with the relative vulnerability to incendiary action of dry bays adjacent to fuel tanks as a function of fuel type. Cai .50 API horizontal gunfire was the threat; a high level of simulation was achieved by having air flow external to and in the dry bays. The results of a wide range of test conditions are presented. The overall conclusion of the investigation was that JP-8 fuel is less susceptible to fire and explosion induced by gunfire and should produce less aircraft structural damage than JP-4.

DD FORM 1 NOV 68 1473

UNCLASSIFIED

Security Classification

1 - a

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Gunfire						
Aviation Fuels, JP-4 and JP-8						
Flammability Limits						
Fuel System Vulnerability						
Aircraft Safety						

/d

**AFAPL-TR-72-83**

**VULNERABILITY OF DRY BAYS ADJACENT TO  
FUEL TANKS UNDER HORIZONTAL GUNFIRE**

*ROBERT G. CLODFELTER*

Approved for public release; distribution unlimited.

*i.c.*

FOREWORD

This report was prepared by Robert G. Clodfelter of the Fire Protection Branch, Fuels and Lubrication Division, Air Force Aero Propulsion Laboratory. The work reported herein was accomplished under Project 3048, "Fuels, Lubrication, and Fire Protection," Task 304807, "Aerospace Vehicle Fire Protection."

This report covers research accomplished from March 1969 through October 1971 and was submitted by the author 21 April 1972.

The author wishes to acknowledge the valuable assistance and contributions of the following: Mr. V. Balachandran, University of Dayton, for assisting with the statistical analysis and Mr. S. Shook, Mr. R. Lillie, and Mr. D. Tolle, Fire Protection Branch, for their efforts in data reduction. Special thanks is given to Mr. J. O'Neill, Federal Aviation Administration, for conducting the test program at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey under Air Force Delivery Order F33615-67-M-5000.

This technical report has been reviewed and is approved.

*C.R. Hudson*

C. R. HUDSON  
Chief, Fuels and Lubrication Division

ABSTRACT

This report deals with the relative vulnerability to incendiary action of dry bays adjacent to fuel tanks as a function of fuel type. Cal .50 API horizontal gunfire was the threat; a high level of simulation was achieved by having air flow external to and in the dry bays. The results of a wide range of test conditions are presented. The overall conclusion of the investigation was that JP-8 fuel is less susceptible to fire and explosion induced by gunfire and should produce less aircraft structural damage than JP-4.

## TABLE OF CONTENTS

SECTION	PAGE
I. INTRODUCTION	1
II. EXPERIMENTAL DESIGN	3
III. TEST DESCRIPTION	4
IV. STATISTICAL PROCEDURES	12
1. Statistical Methods	12
2. Test Description Code	14
3. Assessment of Results	14
V. ANALYSIS OF TEST RESULTS	29
1. Temperature Effect on Standoff Overpressure	29
2. Tank Pressure Effect on Standoff Overpressure	29
3. External Airflow Effect on Standoff Overpressure	32
4. Effect of Void Space Air Changes Per Minute on Standoff Overpressure	35
5. Damage Potential	40
6. Other Factors	48
VI. CONCLUSIONS	50
APPENDIX I. TEST RESULTS	53
APPENDIX II. POSSIBLE CONTAMINATION OF JP-8 TEST BY PREVIOUS JP-4 TEST	83
APPENDIX III. OXYGEN DILUTION DUE TO INCENDIARY FUNCTIONING	85
APPENDIX IV. SAMPLE STATISTICAL PROBLEM	89
APPENDIX V. PROPERTIES OF JP-4 AND JP-8 FUELS	91
REFERENCES	93

## LIST OF ILLUSTRATIONS

FIGURE	PAGE
1. Initial Test Article (17-Gallon Tank)	2
2. Overall View of Engine, Test Weapon, and Test Article	7
3. FAA Gunfire Test Article	8
4. Summary of Test Conditions	9
5. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 9-Inch Standoff	36
6. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 4-Inch Standoff	37
7. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 27-Inch and 27H Standoff	38
8. Overpressure vs. Air Flow in Standoff	41
9. Probability of a Given Overpressure or Greater Occurring	44
10. Probability Distribution for Standoff Overpressure	45
11. Specific Damage Potential for Each Standoff Overpressure	46
12. Total Damage Potential vs. Safe Standoff Overpressure Limit	47
13. Final Oxygen Volume Percent in Dry Bay After Incendiary Reaction	88

## LIST OF TABLES

TABLE	PAGE
I Standoff Fire Duration, JP-4 vs. JP-8 Fuel	15
II Incendiary Burn Times in Standoff, JP-4 vs. JP-8 Fuel	17
III Initial External Fuel Spray Time, JP-4 vs. JP-8 Fuel	19
IV Time to Maximum Standoff Pressure, JP-4 vs. JP-8 Fuel	21
V Maximum Standoff Pressure Rise, JP-4 vs. JP-8 Fuel	23
VI Maximum Standoff Pressure kise, JP-4 vs. JP-8 Fuel	28
VII Temperature Effect on Maximum Standoff Pressure Rise	30
VIII Initial Tank Pressure Effect on Maximum Standoff Pressure Rise	31
IX External Air Flow Effect on Maximum Standoff Pressure Rise	33
X Effect of ACPM on Maximum Standoff Pressure Rise	39
XI Air Flow Effect on Maximum Standoff Pressure Rise	42
XII Summation of Results	49
XIII Maximum Standoff Pressure of First vs. Last JP-8 Shot of a Series	84
XIV Sample Statistical Problem (Random Numbers 0 to 35) B=0.6A (By Definition)	90
XV Properties of JP-4 and JP-8 Fuels	92

SECTION I  
INTRODUCTION

During March 1969 an extensive gunfire test program to evaluate the vulnerability of JP-4 and JP-8 fuels to external fires induced by incendiary gunfire was initiated with FAA (NAFEC), Atlantic City, New Jersey, by redirection of effort under an existing Delivery Order with the AFAPL. The term external fires refers to sustained burning outside the fuel tank (i.e., void space, dry bay areas) either within or outside the simulated aircraft structure. The program with the FAA represented an extension of a small-scale liquid space gunfire test effort conducted in-house by the Air Force Aero Propulsion Laboratory in 1968. During this preliminary testing, the low volatility fuel, JP-8, exhibited external sustained fires only 3.1% of the time, whereas the standard Air Force fuel, JP-4, sustained fires 68.6% of the time. The test article used in the initial program is shown in Figure 1 and details are given in Reference 1.

The FAA program used three larger replica test tanks with more realistic configurations and control of fuel system operating parameters (such as internal pressurization) and considered the effects of internal dry bay ventilation rates as well as airflow exterior to the simulated fuselage on the ignitability, flame propagation, and flame sustainment properties of JP-4 and JP-8 fuels. The FAA long-range gunfire test program involves several phases, but initial emphasis was directed to the fuselage replica tanks and the relative vulnerability of JP-4 and JP-8 fuels.

The purpose of this report is to provide a detailed assessment of the horizontal gunfire tests conducted by the FAA through June 1971.

The results presented herein include a refinement and an extension of the information given in AFAPL-TR-70-93 "AFAPL Aircraft Fire Test Program with FAA 1967-1970," dated June 1971.

AFAPL-TR-72-83



Figure 1. Initial Test Article (17-Gallon Tank)

SECTION II  
EXPERIMENTAL DESIGN

Several items must be considered in designing a gunfire test program to assess aircraft survivability/vulnerability. All programs have cost and time constraints. One approach that may be taken is to strive for a very high degree of simulation. Real aircraft fuel tanks may be used, but the threat and operational environment must also be simulated. Even with a very high degree of simulation of this environment, the test results are still estimates based on statistical sampling and can be statistically valid only with sufficient sampling. Many tests with a high level of simulation may conflict with the cost-time constraints; therefore, the scope of the test effort may have to be restricted in order to obtain valid results. Unfortunately, if the scope is too limited, making general conclusions applying to conditions not specified in the test would be impossible. This is true because high variance is associated with most response variables which quantify the projectile-fuel tank interaction, regardless of the level of simulation achieved in the test program.

The approach taken in this effort was to design an experiment which would be statistically valid yet provide general conclusions. Trade-offs were made in the level of simulation in order to accomplish as many tests under as wide a range of conditions as possible. The number of times each set of test conditions was repeated was based on statistical principles and a projection of the expected test results. In other words, if a large difference in response was expected between two sets of test conditions, a smaller number of repeats would be required than if only a small difference was expected. An example which illustrates this point is presented in Appendix IV. All factors which were not controllable, such as ambient temperature, projectile dynamics, etc., should have entered into the program in a random way. Complete randomization of the factors would have made the test sequencing unmanageable, and trade-offs again were required; however, some effort to randomize the uncontrollable parameters was included in the program to ensure that the test results were not biased by the uncontrollable factors.

SECTION III  
TEST DESCRIPTION

The objective of the test program was to determine the relative vulnerability of JP-4 and JP-8 fuels to fires in areas outside the fuel tank (i.e., void space, and dry bay areas--also referred to as standoff). For most of the test program, the only variables were fuel type, void space volume, void space ventilation, and external airflow. All other factors were controlled at a fixed value. The following test conditions were established for the initial phase of the test program:

1. Fuels: JP-4 and JP-8 (118°F flash point)
2. Projectile type and velocity: Cal .50 API, 2400 ft/sec.
3. Projectile trajectory: Horizontal, impact angle of 30°.
4. Tank volume: Approximately 90 gallons
5. Fuel temperature: 90°F ± 5
6. Fuel tank pressure: 5 psig
7. Fuel height: 18 inches
8. Impact point: Center of liquid, approximately 9 inches below the fuel/ullage interface.
9. Ullage: 25% of tank volume
10. External air velocity: 0, 90, 125, and 300 knots
11. Standoff distance (striker plate to tank distance - also referred to as void space): 1, 4, and 9 inches
12. Void space ventilation:
  - a. 18 ACPM\* at 90 knots external airflow and 4 inch test article
  - b. 75 ACPM at 90 knots external airflow and 4 inch test article
  - c. 58 ACPM at 300 knots external airflow and 4 inch test article
  - d. 180 ACPM at 300 knots external airflow and 4 inch test article
  - e. 23 ACPM at 90 knots external airflow and 9 inch test article
  - f. 96 ACPM at 90 knots external airflow and 9 inch test article

- g. 101 ACPM at 300 knots external airflow and 9 inch test article.
- h. 325 ACPM at 300 knots external airflow and 9 inch test article.

\*ACPM - Air Changes Per Minute

The projectile velocity (2400 ft/sec) and striker plate (first impact surface consisting of 2 plates made of 0.125" and 0.090" 2024T3 aluminum) configuration were selected to give maximum incendiary functioning in the void volume. These were selected by making two shots into each of three standoff distances (1, 4, and 9 inches) at three projectile velocities (1800, 2400, and 2900 ft/sec) and noting the incendiary burn times. From the 18 shots, a projectile velocity of 2400 ft/sec produced the longest incendiary burn time (10 to 18 milliseconds, on the average). The biggest ignition source possible with a Cal .50 API, therefore, was available to ignite any fuel in the void space. External airflow around the test article was generated by ducting fan air from a TF-33 engine.

In addition to the above, a few tests were conducted with other test conditions: (1) polyurethane flame-arresting foam in the dry bay; (2) polyurethane flame-arresting foam in the fuel tank; (3) fuel temperature other than 90°F; (4) fuel tank pressure other than 20 psia; and (5) various sizes of dry bays on both the projectile exit side and projectile entrance side of the test article.

Photographic data was recorded by two cameras at 3500 and 7000 frames per second, color film. The test article was viewed through the plexiglass top plate. Overall film coverage was provided by a camera operating at 500 frames per second.

An overall view of the test range is given in Figure 2, and a typical test article designed to simulate a fuselage fuel tank is shown in Figure 3. Figure 4 shows the various test article configurations and gives a summary of the test conditions. Detailed test conditions and results are presented in Appendix I; additional background information on the test procedures are given in References 2 and 3. Appendixes II

**AFAPL-TR-72-83**

and III present two potential problem areas considered prior to detailed analysis of the test results. Appendix V gives the properties of the two fuels used in the test program.

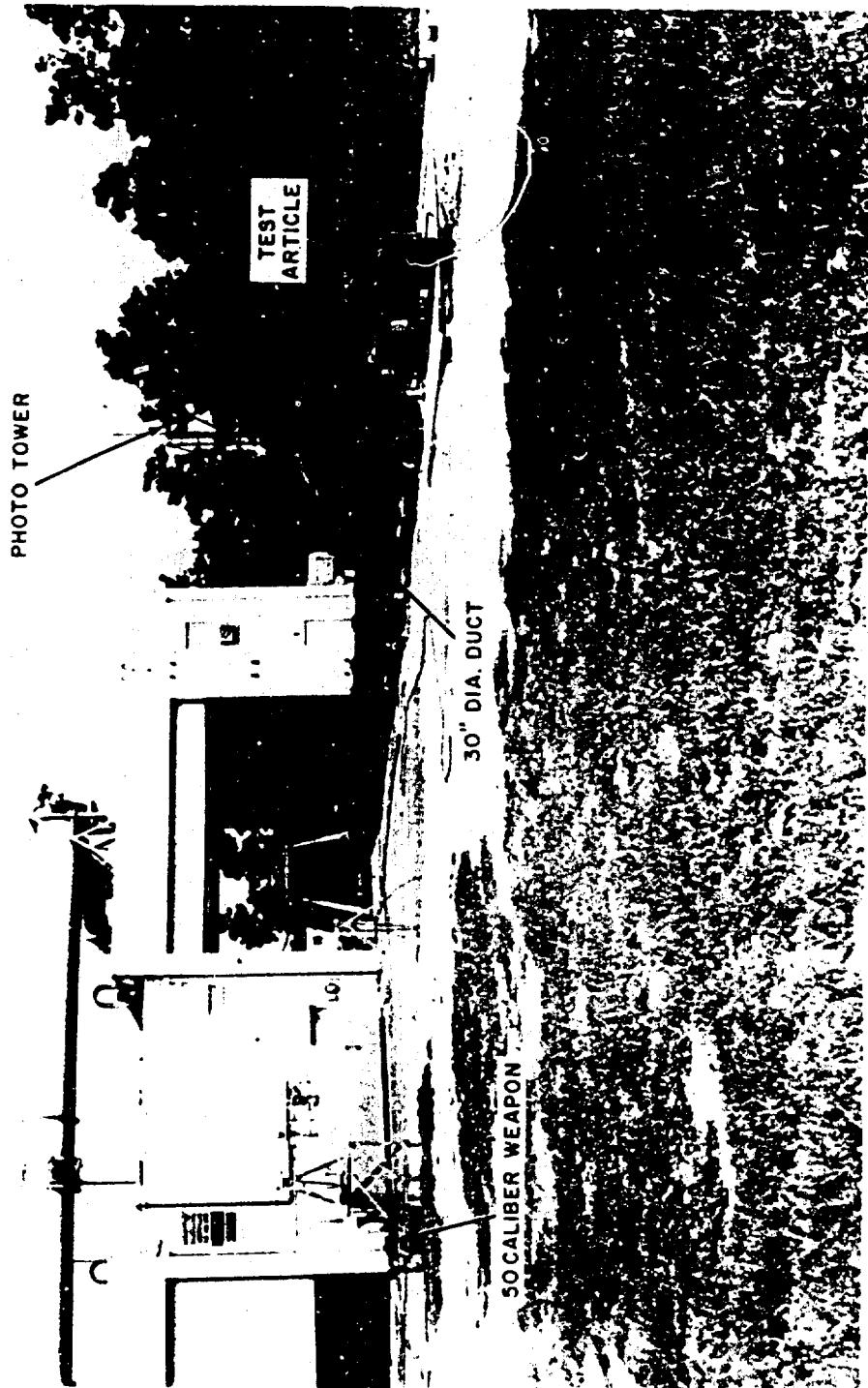


Figure 2. Overall View of Engine, Test Weapon, and Test Article

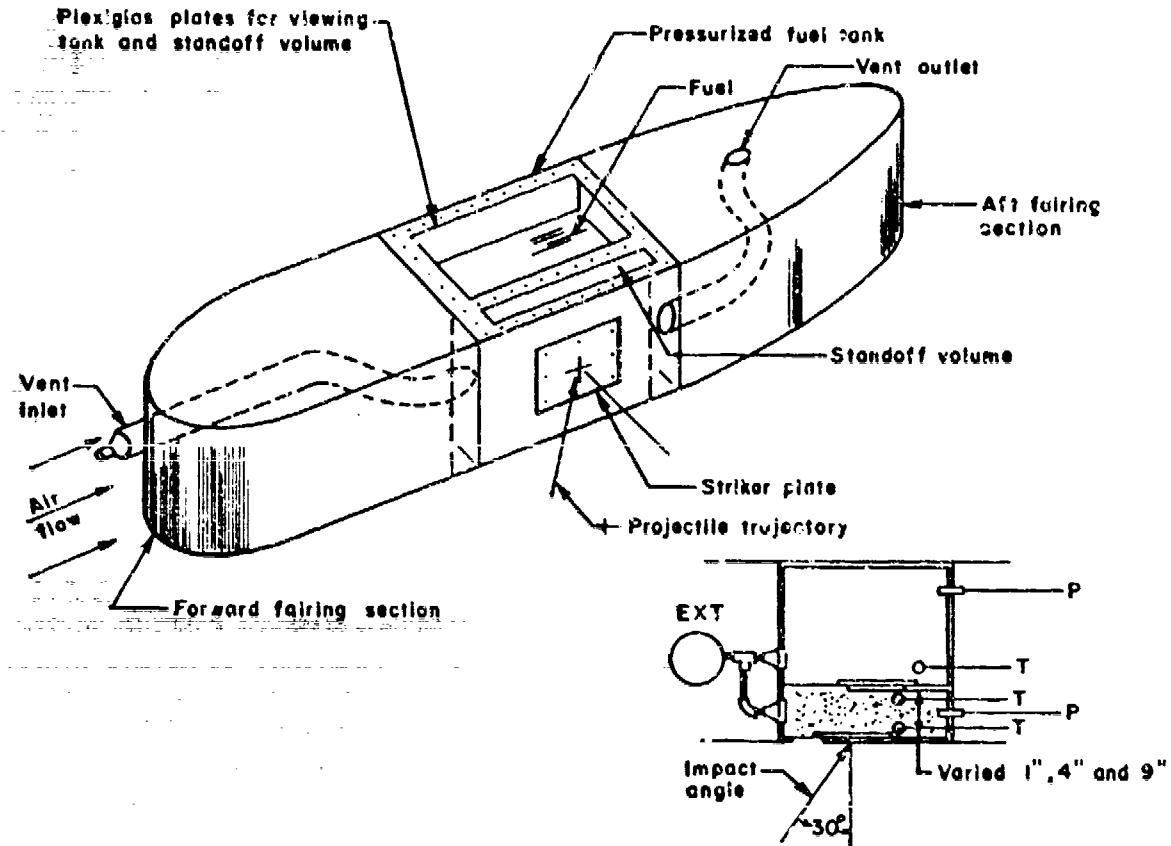


Figure 3. FAA Gunfire Test Article

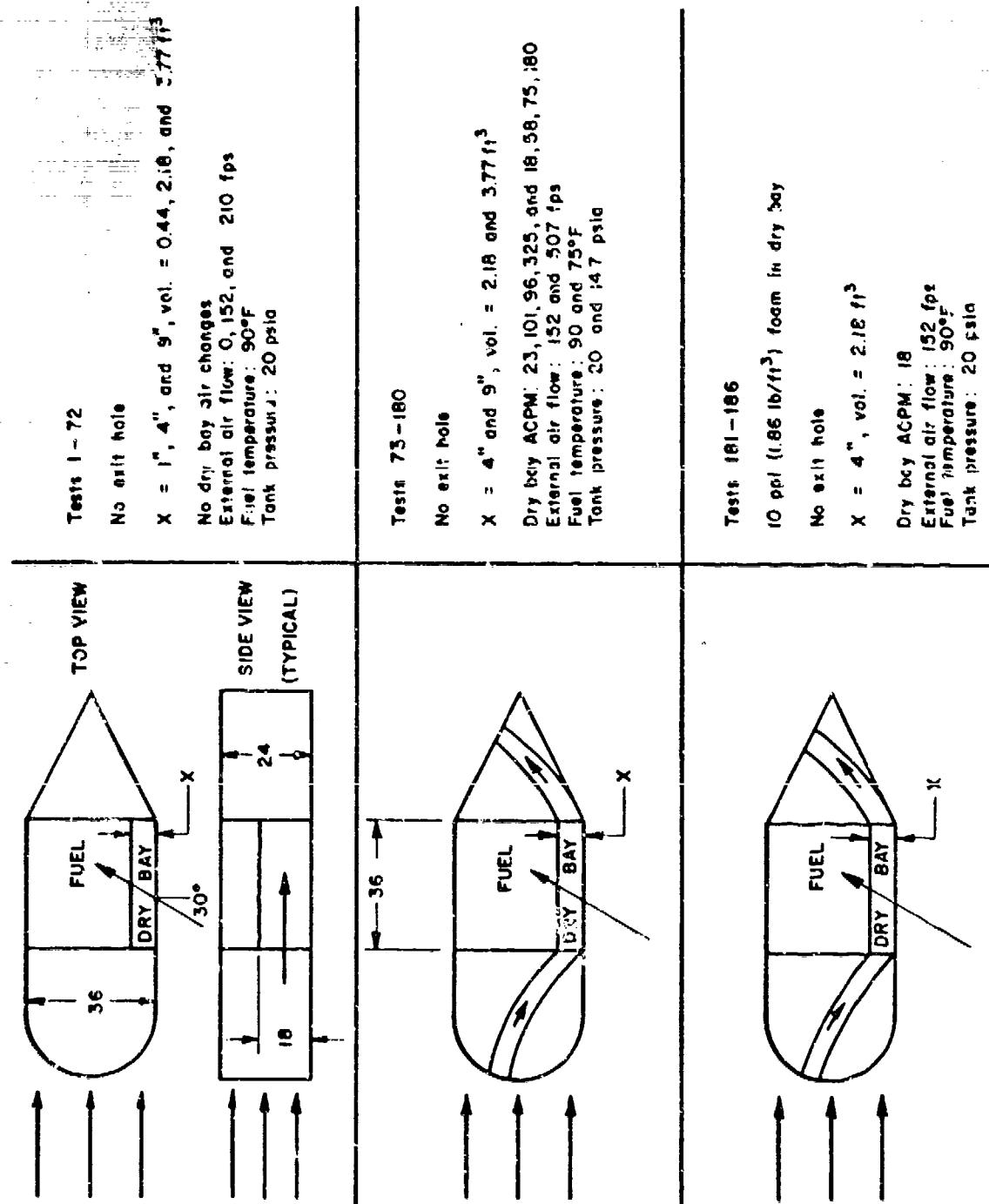


Figure 4. Summary of Test Conditions

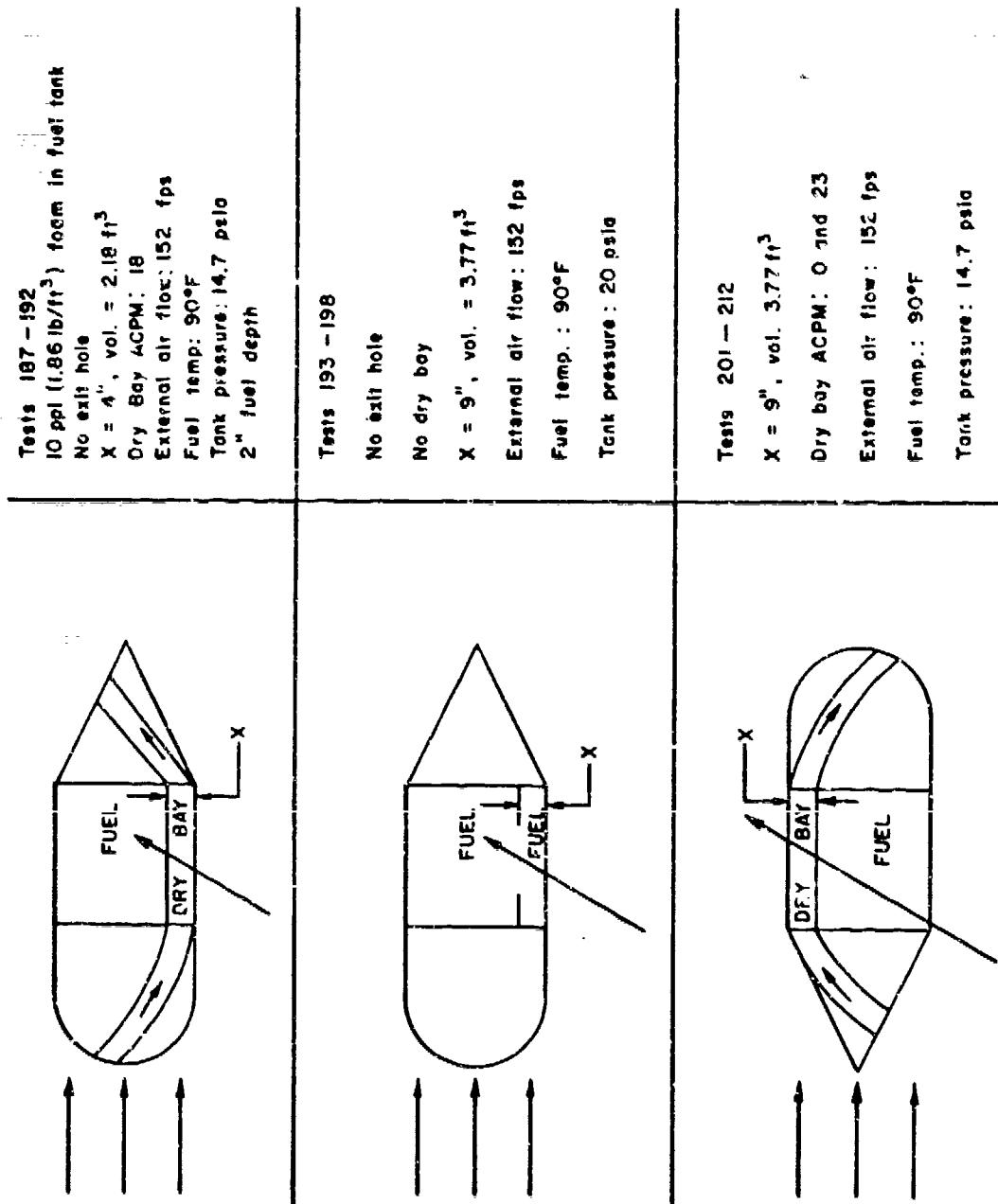


Figure 4. Continued

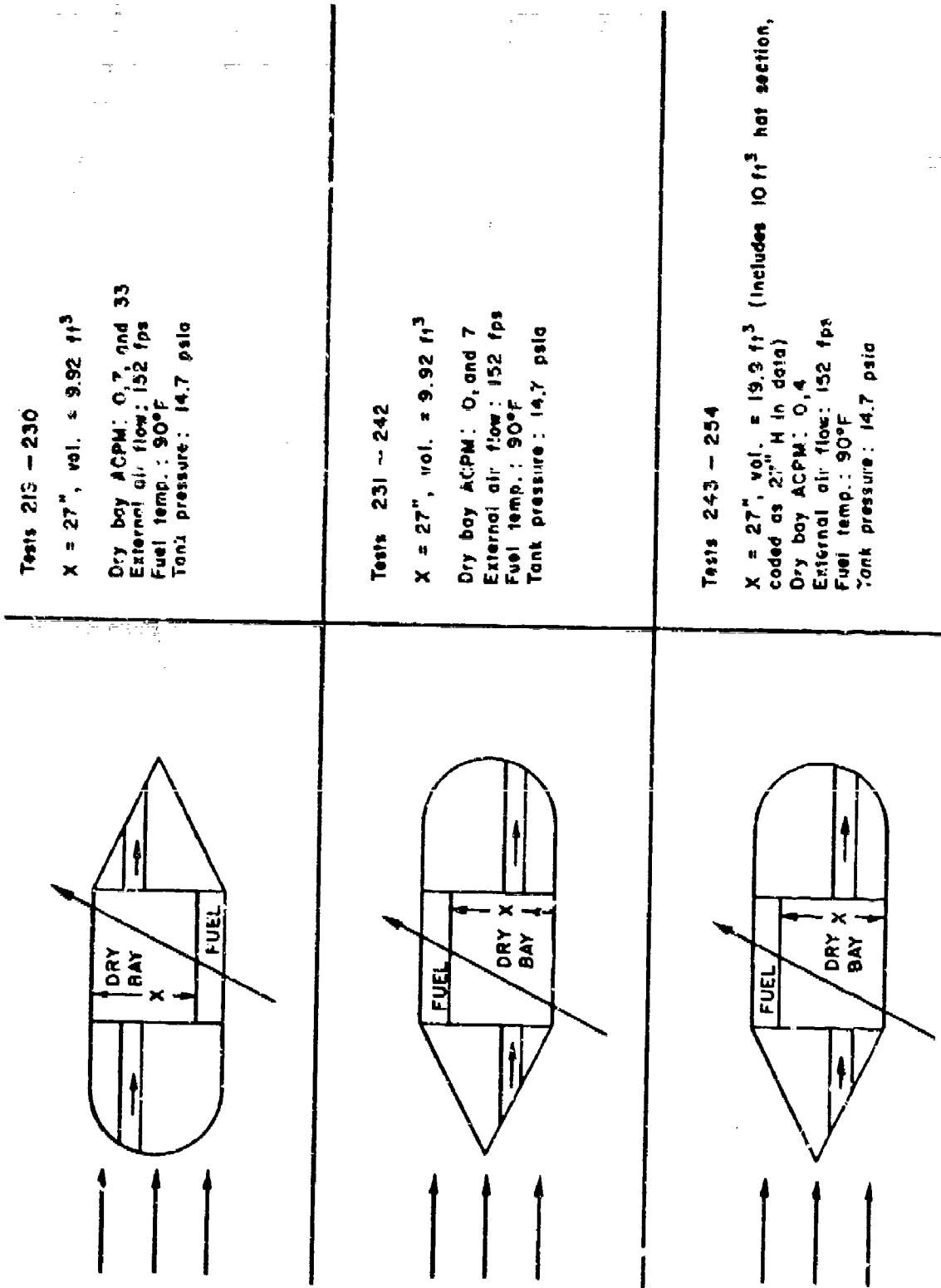


Figure 4. Continued

SECTION IV  
STATISTICAL PROCEDURES

**1. STATISTICAL METHODS**

The first step in the analysis of the test results was to compare the recorded responses for the two fuels (JP-4 and JP-8) under identical initial conditions. Statistical methods were used in the comparison to assess the question, "If a difference between the response variables for the two fuels is noted, is the difference small enough that it could have occurred by chance or is it so large that it most probably is a true measure of the difference between the two fuels?" The following statistical expressions were used in this analysis (the reader may refer to the many textbooks on the subject for details).

The sample mean  $\bar{X} = \frac{1}{n} \sum_{i=1}^n x_i$ , where  $x_1, x_2 \dots x_n$  denote the responses of the random variable  $X$ , and  $n$  is the size of the sample, provides an unbiased and minimum variance estimate on the population mean  $\mu$ , which is unknown.

The sample variance  $s^2 = \left[ \sum_{i=1}^n (x_i - \bar{x})^2 \right] / (n - 1)$  provides an unbiased estimate of the population variance  $\sigma^2$ . Moreover if  $s_1^2$  and  $s_2^2$  are two independent estimates of the same unknown,  $\sigma^2$  based on  $n_1$  and  $n_2$  samples, respectively, then

$$F = s_1^2 / s_2^2 \quad \text{or} \quad s_2^2 / s_1^2$$

(the ratio selected in such a way that the larger  $s^2$  is in the numerator).

This yields an  $F$  with  $n_1 - 1$  and  $n_2 - 1$  degrees of freedom for the numerator and denominator, respectively, assuming  $s_1^2 > s_2^2$ , which could be compared with  $F$  distribution values for homogeneity of variance.

The  $T$  test which was used to test for the significant difference of means was based on the assumption that there was "homogeneity of variance." Thus, the  $F$  ratio was used as a measure to check the validity

of this underlying assumption. Values of the F ratio near one are desired. Once such an assumption is established as valid, then any difference in the data is solely due to the difference in means. In a large number of cases in Table I, the F ratio was not significant, which ensured homogeneity of variances. Hence we made a general assumption of "homogeneity of variance," which enabled us to use the T test for the difference in means.

The criterion for comparing the means was the Student T test.

$$T = \frac{\left| \bar{x}_1 - \bar{x}_2 \right|}{\left( \frac{(n_1 - 1) \sigma_1^2 + (n_2 - 1) \sigma_2^2}{n_1 + n_2 - 2} \right)^{1/2}} \left( \frac{n_1 n_2}{n_1 + n_2} \right)^{1/2}$$

A  $T_c$  value was chosen to test the results. If the calculated T is less than  $T_c$ , there is probably no significant difference between the means. If the calculated T is larger than  $T_c$ , the two means are not necessarily different, but it provides a strong argument in favor of a difference.

A  $T_c$  value associated with the 95 percentile point was used in the comparison. This is equivalent to a 10% error for the "two-tail" problem of interest; that is, if 100 sets of response variables are to be compared, at least 90 sets would verify the conclusion and no more than 10 sets would not. Values of  $T_c$  are given in most statistical reference books as a function of degree of freedom ( $DF = n_1 + n_2 - 2$ ) where, for our tests,  $n_1$  is the number of tests with JP-4, and  $n_2$  the number with JP-8.

The results of the statistical analysis for the two fuels are given in Tables I through V. Reference Appendix IV, which illustrates the inability to show a difference between means when that difference is small and only a limited number of tests are conducted.

## 2. TEST DESCRIPTION CODE

The following codes designate the items given under test conditions (a,b,c,d,e,f) in Tables I thru V.

a = Fuel Type (4 = JP-4, 8 = JP-8)

b = Fuel Temperature ( $^{\circ}$ F  $\pm$  5  $^{\circ}$ F)

c = Standoff Distance (inches) ex. 27 = 27 inches standoff front side  
27B = 27 inches standoff back side  
27H = 27 inches standoff front side  
with hat section

d = External air flow (Knots  $\pm$  10 knots)

e = Air changes per minute in standoff (ACPM  $\pm$  2 ACPM)

f = Initial fuel tank pressure (psia  $\pm$  2 psi)

## 3. ASSESSMENT OF RESULTS

The following discussion of the test results considers both the statistical information of Tables I thru V and other factors of the "real world" which could not be included in the statistical analysis.

### a. Standoff Fire Duration (Table 1)

From the "real world" point of view, it is possible for the Standoff Fire Duration to be dependent on the fuel type. Unfortunately, the total Standoff Fire Duration was unknown for several tests because the data camera ran out of film before the fire stopped. This occurred during 21 of 98 tests with JP-4 and 29 of 92 tests with JP-8, so about 1/4 of the input data indicated less than the actual standoff fire duration. With this limitation, the following general observations were made.

a. At very low dry bay ACPM, the standoff fire duration for JP-8 was 2 to 5 times longer than for JP-4 (typically 350 vs 80 msec). JP-4 burns faster and thus depletes the available oxygen faster.

TABLE I  
STANDOFF FIRE DURATION FOR JP-4 VS. JP-8 FUELS (MSEC)

No.	Test Description a b c d : f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )	F	$T^*$	$T_c$	REMARKS
			JP-4	JP-8					
1	(-.90,9,0,0,20)	4	5	2211	61,627	71	310	27.9	1.68
2	(-.90,9,90,0,20)	5	5	3724	8677	97	432	2.3	6.73**
3	(-.90,9,90,23,20)	6	5	3190	436	312	279	7.3	1.24
4	(-.90,9,90,96,20)	6	3	4217	1,318,169	207	1051	431.2	1.65
5	(-.90,9,300,101,20)	6	6	9077	8103	239	262	1.1	0.43
6	(-.90,91,300,325,20)	6	4	8200	554	163	65	14.8	2.53**
7	(-.90,4,0,0,20)	6	6	35442	4116	252	403	8.5	1.87**
8	(-.90,4,90,0,20)	5	6	4435	3975	75	330	1.1	6.50**
9	(-.90,4,90,18,20)	5	4	18,404	8024	204	285	2.29	1.03
10	(-.90,4,90,75,20)	3	4	3325	3,738,790	293	1333	1124	0.91
11	(-.90,4,300,58,20)	4	3	1304	4177	331	350	3.2	.51
12	(-.50,4,300,180,20)	4	4	10,079	3,799,744	236	2580	377	2.40**
13	(-.90,1,0,0,20)			Insufficient Data					
14	(-.90,1,90,0,20)	2	2	6161	6845	257	378	1.1	1.50
15	(-.75,9,90,25,20)			Insufficient Data					2.92

TABLE I (CONTINUED)

No.	Test Description B b C d e f	n	VARIANCE ( $\sigma^2$ )			MEAN ( $\bar{X}$ )			F Ratio	T	$T_c^*$	REMARKS
			JP 4	JP-8	JP-4	JP-8	JP-4	JP-8				
16	{-, 90, 9, 96, 23, 15}	4	4	13,318	43,303	397	269	3.6	1.03	1.94		
17	{-, 75, 9, 90, 97, 20}	3	2	2,473	13,945	249	380	5.6	1.80	2.35		
18	{-, 90, 9, 90, 97, 15}	2	3	288	4,722	518	422	16.4	1.85	2.35		
19	{-, 90, 4, 90, 18, 20}			Insufficient Data								
20	{-, 90, 4, 90, 18, 15}	3	3	56,785	176	169	477	322.0	2.24	2.13		
21	{-, 90, 0, 90, 0, 20}	3	3	N/A								No standoff
22	{-, 90, 98, 90, 0, 15}	3	3	0	0	0	0	U	U	2.13	9"	standoff backside
23	{-, 90, 98, 90, 23, 15}	3	3	0	0	0	0	U	U	2.13	9"	standoff backside
24	{-, 90, 278, 90, 0, 15}	3	3	0	8.3	0	1.7	U	1.00	2.13	27"	standoff backside
25	{-, 90, 278, 90, 7, 15}	3	2	50,181	45,600	129	150	1.1	.10	2.35	27"	standoff backside
26	{-, 90, 278, 90, 33, 15}	3	3	0	44,652	0	122	U	1.00	2.13	27"	standoff backside
27	{-, 90, 27, 90, 0, 15}	3	3	1,716	42,245	315	119	24.6	1.62	2.13		
28	{-, 90, 27, 90, 7, 15}	3	3	34,951	35,557	215	217	1.02	0.02	2.35		
29	{-, 90, 274, 90, 0, 15}			Insufficient Data								
30	{-, 90, 274, 90, 4, 15}			Insufficient Data								

\*  $T_c$  = T value at 25.0% (10% error - two tail)

\*\* Values showing statistical differences

TABLE II  
INCENDIARY BURN TIMES IN STANDOFF FOR JP-4 vs. JP-8 FUELS (MSEC)

No.	Test Description a b c d e f	n		VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{x}$ )		F Ratio	$T^*$	$T_c$	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-.90,9,0,0,20)	6	5	23	459	7	29	20.4	2.40**	1.83	
2	(-.90,9,62,0,20)	6	5	306	437	22	52	1.4	2.66**	1.83	
3	(-.90,9,90,23,20)	6	5	4	64	9	14	14.9	1.69	1.83	
4	(-.90,9,90,96,20)	6	4	125	0.7	21	7	186.9	2.48**	1.86	
5	(-.90,9,300,101,20)	6	6	1	35	8	13	29.1	2.10**	1.81	
6	(-.90,9,300,325,20)	6	4	89	234	20	27	2.6	.97	1.86	
7	(-.90,4,0,0,20)	6	6	82	37	32	-	2.2	4.61**	1.81	
8	(-.90,4,90,0,20)	5	6	148	0.4	25	8	370.8	3.53**	1.83	
9	(-.90,4,90,18,20)	5	5	17	2	10	7	7.9	1.42	1.86	
10	(-.90,4,90,75,20)	5	4	3	30	10	11	11	.22	1.90	
11	(-.90,4,300,58,20)	4	4	1	0.7	7	3	2	5.66**	1.94	
12	(-.90,4,300,180,20)	4	4	5	16	9	15	3.2	2.43**	1.94	
13	(-.90,1,0,0,20)	4	5	393	639	47	33	2.1	0.78	1.90	
14	(-.90,1,90,0,20)	3	4	86	0.7	12	2	127.5	2.14**	2.02	
15	(-.75,9,90,23,20)	2	3	5	4	10	8	1.0	0.96	2.35	

TABLE II (CONTINUED)

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )			MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			JP-4	JP-8	JP-4	JP-8	JP-4				
16	(-, 90, 9, 90, 23, 15)	4	4	2	3	10	8	1.6	1.44	1.94	
17	(-, 75, 9, 90, 97, 20)	3	2	0.3	13	12	10	37.5	1.13	2.35	
18	(-, 90, 9, 90, 97, 15)	3	3	2	4	7	8	1.9	0.22	2.13	
19	(-, 90, 4, 90, 18, 20)	3	3	2	Insufficient Data	7	8				10 PPI foam in standoff
20	(-, 90, 4, 90, 18, 15)	3	3	2	1	7	8	2.3	.63	2.13	10 PPI foam in tank
21	(-, 90, 0, 90, 0, 20)			N/A							No standoff
22	(-, 90, 9B, 90, 0, 15)	3	3	0	0	0	0	U	2.13	9"	S.O. backside
23	(-, 90, 9B, 90, 23, 15)	3	3	0	0	0	0	U	2.13	9"	S.O. backside
24	(-, 90, 27B, 90, 0, 15)	3	3	0.3	0.3	0.3	2	1.0	2.83**	2.13	27" S.O. backside
25	(-, 90, 27B, 90, 7, 15)	3	2	7	.5	3	4	14	.25	2.35	27" S.O. backside
26	(-, 90, 27B, 90, 33, 15)	2	2	3	0	2	0	U	1.0	2.92	27" S.O. backside
27	(-, 90, 27, 90, 0, 15)	3	3	1	19	7	5	14.3	0.90	2.13	
28	(-, 90, 27, 90, 7, 15)	3	3	16	.3	4	4	49	00	2.13	
29	(-, 90, 27H, 90, 0, 15)			Insufficient Data							27" standoff with hat section
30	(-, 90, 27H, 90, 4, 15)			Insufficient Data							27" standoff with hat section

\*  $T_c$  = T value at 95.0% (10% error - two tail)

\*\* Values showing statistical difference

TABLE III  
INITIAL EXTERNAL FUEL SPRAY TIME FOR JP-4 VS. JP-8 FUEL (MSEC)

No.	Test Description a b c d e f	n		VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ , JP-4      JP-8)		F Ratio	T	$\gamma_c^*$	REMARKS
		JP-4	JP-8	JP-4	JP-8	JP-4	JP-8				
1	(-,90,9,0,0,20)	5	5	9,435	241,065	99	1,028	25.6	4.15**	1.86	
2	(-,90,9,90,0,20)	5	5	141,879	89,872	401	532	1.6	0.61	1.86	
3	(-,90,9,90,23,20)	3	2	25,541	242	219	316	105.5	.82	2.35	
4	(-,90,9,90,96,20)	6	4	10,178	25	126	34	407.1	1.80	1.86	
5	(-,90,9,300,101,20)	6	6	7,131	5,801	121	126	1.2	0.11	1.81	
6	(-,90,9,300,325,20)	6	4	25,902	684	121	123	37.9	.22	1.86	
7	(-,90,4,0,0,20)	6	6	51,244	187,793	309	587	3.7	1.40	1.81	
8	(-,90,4,90,0,20)	5	6	45,197	43,620	249	845	1.1	4.59**	1.83	
9	(-,90,4,90,18,20)	6	6	180	3,209	61	57	17.8	0.15	1.81	
10	(-,90,4,90,75,20)	5	4	3,930	9,559	86	191	2.4	1.97**	1.90	
11	(-,90,4,300,58,20)	4	2	321	0	39	22	U	1.23	2.13	
12	(-,90,4,300,180,20)	4	4	172	209	29	37	1.2	0.82	1.94	
13	(-,90,1,0,0,20)	4	5	1,444	523	19	35	2.8	0.78	1.90	
14	(-,90,1,90,0,20)	3	4	508	110,257	46	312	217	1.35	2.02	
15	(-,75,9,90,23,20)	1	3	U	148,933	234	763	U	U	2.92	

TABLE III (CONTINUED)

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			JP-4	JP-8	JP-4	JP-8				
16	(-, 90, 9, 90, 23, 15)	4	1	2,798	U	276	604	U	U	2.35
17	(-, 75, 9, 90, 97, 20)	3	3	132,933	221,449	639	843	1.7	0.59	2.13
18	(-, 90, 9, 90, 97, 15)	2	2	20,808	1,976,072	552	2,026	95	1.48	2.92
19	(-, 90, 4, 90, 18, 20)	3	2	14,196	2,178	172	113	6.5	0.64	2.35
20	(-, 90, 4, 90, 18, 15)			Insufficient Data						10 PPI foam in standoff 10 PPI foam in tank
21	(-, 90, 0, 90, 0, 20)	3	3	0	0	0	0	U	U	2.13 No standoff
22	(-, 90, 98, 90, 0, 15)	3	3	0	0	0	0	U	U	2.13 9" Standoff backside
23	(-, 90, 98, 90, 23, 15)	3	3	0	0	0	0	U	U	2.13 9" Standoff backside
24	(-, 90, 27B, 90, 0, 15)	3	3	0	0	0	0	U	U	2.13 27" standoff backside
25	(-, 90, 27B, 90, 7, 15)	3	2	0	0	0	0	U	U	2.35 27" standoff backside
26	(-, 90, 27B, 90, 33, 15)	3	3	0	0	0	0	U	U	2.13 27" Standoff backside
27	(-, 90, 27, 90, 0, 15)			Insufficient Data						
28	(-, 90, 27, 90, 7, 15)			Insufficient Data						
29	(-, 90, 27H, 90, 0, 15)			Insufficient Data						27" standoff with hat section
30	(-, 50, 27H, 90, 4, 15)			Insufficient Data						27" standoff with hat section

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Values showing statistical difference

**TABLE IV**  
**TIME TO MAXIMUM STANDOFF PRESSURE FOR JP-4 vs. JP-8 FUEL (MSEC)**

No.	Test Description n P C 1 c f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			JP-4	JP-8	JP-4	JP-8				
1	(-.30,.1,C,0,20)	2	.5	4,203	1,824	58	84	2.3	0.71	1.90
2	(-.30,.5,30,0,20)	6	5	1,359	700	55	77	1.9	1.11	1.83
3	(-.90,.9,40,22,20)	5	5	292	226	33	36	1.3	0.35	1.86
4	(-.90,9,90,96,20)	6	4	783	78	32	18	10.0	0.94	1.86
5	(-.90,9,300,101,20)	6	5	305	40	32	29	7.6	0.41	1.83
6	(-.90,9,300,325,20)	6	3	52	.33	35	26	157.2	2.00**	1.90
7	(-.90,4,0,0,20)	6	4	76	6,967	27	76	89.3	1.48	1.86
8	(-.90,4,90,0,20)	3	2	3	41	20	27	13.5	1.81	2.35
9	(-.90,4,90,18,20)	6	5	1,353	105	58	101	12.9	2.52**	1.83
10	(-.90,4,90,75,20)	5	4	927	329	83	44	2.8	2.27**	1.90
11	(-.90,4,300,58,20)	4	4	9	461	82	82	53.2	0.53	1.94
12	(-.90,4,300,180,20)	4	4	1,622	2,444	57	71	1.5	0.42	1.94
13	(-.90,1,0,0,20)				Insufficient Data					
14	(-.90,1,90,0,20)				Insufficient Data					
15	(-.75,9,90,23,20)	2	3	545	91	48	40	6.0	0.53	2.35

TABLE IV (CONTINUED)

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			JP-4	JP-8	JP-4	JP-8				
16	(-.90,9,90,23,15)	4	96	355	28	43	3.7	1.41	1.94	
17	(-.75,9,90,97,20)	3	3	17	9	53	47	1.9	1.91	2.13
18	(-.90,9,90,97,15)	3	3	21	36	46	25	14.1	2.06	2.13
19	(-.90,4,90,18,20)									10 PPI foam in standoff
20	(-.90,4,90,18,15)	3	3	14	2	37	35	6.1	0.57	10 PPI foam in tank
21	(-.90,9,90,0,20)	3	3	N/A						No standoff
22	(-.90,98,96,0,15)									9" standoff backside
23	(-.90,98,90,23,15)									9" standoff backside
24	(-.90,27B,90,0,15)									27" standoff backside
25	(-.90,27B,90,7,15)	1	1	U	U	86	79	U	U	27" standoff backside
26	(-.90,27B,90,33,15)	0	1	U	U	U	316	U	U	27" standoff backside
27	(-.90,27,90,0,15)	3	2	4,789	7,688	139	72	1.6	0.97	2.35
28	(-.90,27,90,7,15)	2	3	1,250	5,200	103	77	4.2	0.46	2.35
29	(-.90,27H,90,0,15)	2	3	1,152	6,480	147	177	5.6	0.48	2.35
30	(-.90,27H,90,4,15)	3	3	252	7,783	92	114	30.9	0.43	2.13

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Values showing a statistical difference

TABLE V  
MAXIMUM STANDOFF PRESSURE RISE FOR JP-4 VS. JP-8 FUEL (psi  $\times 10^3$ )

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		$\bar{r}$ Ratio	$T^*$	$T_c$	REMARKS
			JP-4	JP-8	JP-4	JP-8				
1	(-.90,9,0,0,20)	4	5	18,244	2,569	229	108	7.1	1.88	1.90
2	(-.90,9,90,0,20)	6	5	18,653	1,115	231	102	16.7	2.05**	1.83
3	(-.90,9,90,23,20)	6	5	370	1,299	54	82	1.49	1.43	1.83
4	(-.90,9,90,96,20)	6	4	369	455	61	67	1.23	0.46	1.85
5	(-.90,9,300,101,20)	6	5	32	325	64	56	4.0	0.87	1.83
6	(-.90,9,300,325,20)	6	3	9,856	1,185	129	201	8.3	1.20	1.90
7	(-.90,4,0,0,20)	6	6	21,473	3,076	250	119	7.0	2.05**	1.81
8	(-.90,4,90,0,20)	5	6	31,899	1,088	137	44	29.3	0.10	1.83
9	(-.90,4,90,18,20)	6	5	306	190	40	52	1.6	1.29	1.83
10	(-.90,4,90,75,20)	5	4	2,129	1,276	64	71	1.7	0.25	1.90
11	(-.90,4,300,58,20)	4	4	71	156	45	61	2.2	2.13**	1.94
12	(-.90,4,300,180,20)	4	4	2,613	1,748	77	54	1.5	0.72	1.94
13	(-.90,1,0,0,20)	3	4	17	259	5	18	14.9	1.37	2.02
14	(-.90,1,90,0,20)	4	4	4	268	9	24	73.0	1.82	1.94
15	(-.75,9,90,23,20)	2	3	1,800	709	102	57	2.5	1.49	2.35

TABLE V (CONTINUED)

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )			MEAN ( $\bar{Y}$ )	$F$	$T^*$	$T_c^*$	REMARKS
			JP-4	JP-5	JP-4					
16	(-,90,9,90,23,15)	4	4	120	260	58	57	2.2	0.10	1.94
17	(-,75,9,90,97,20)	3	3	201	516	73	96	2.6	1.51	2.13
18	(-,90,9,90,97,15)	3	3	36	952	66	123	26.5	3.16**	2.13
19	(-,90,4,90,18,20)	3	3	9	0	3	0	U	1.89	2.13
20	(-,90,4,90,18,15)	3	3	1	9	11	15	7.0	2.47**	2.13
21	(-,90,0,90,0,20)	3	3	N/A						10 PPI foam in standoff
22	(-,90,98,90,0,15)	3	3	0	0	0	0	U	U	9" standoff backside
23	(-,90,98,90,23,15)	3	3	0	33	0	3	U	1.00	9" standoff backside
24	(-,90,27B,90,0,15)	3	3	0	0	0	0	U	U	27" standoff backside
25	(-,90,27B,90,7,15)	3	2	1,412	26,912	24	116	19.1	1.02	2.35
26	(-,90,27B,90,33,15)	3	3	3	265	1	11	88.4	1.09	2.13
27	(-,90,27,90,0,15)	3	3	69	1,669	337	27	24.1	12.89**	2.13
28	(-,90,27,90,7,15)	2	3	613	50	117	17	12.2	7.05**	2.35
29	(-,90,27H,90,0,15)	3	3	73,625	1,460	271	114	53.8	0.96	2.13
30	(-,90,27H,90,4,15)	3	3	11,191	1,873	265	53	1.0	3.14**	2.13

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Values showing a statistical difference

b. At high dry bay ACPM, no clear difference exists between the two fuels, although as ACPM increases, the burn times generally tend to increase for both fuels.

b. Incendiary Burn Time in Standoff (Table II)

It was not expected that incendiary burn time would be a function of fuel type. Although the statistical results show cases where it appears significant, the direction of significance was mixed. Under five test conditions the incendiary burn time was significantly longer for JP-4, and under five other test conditions it was significantly longer for JP-8. These mixed results were most likely due to our inability to read the film properly and determine the difference between incendiary burn and fuel fire. Moreover, out of the 10 test conditions where significant difference in the means is seen, as evidenced by the larger T value, 8 also show a significantly larger F value, which explains the mixed results as being due to the masking effect of the variance. In other words, the significant difference in the means is well within the variability seen in the two distributions. Thus, the difference in the means cannot prove that either JP-4 or JP-8 affected the incendiary burn time.

c. Initial External Fuel Spray Time (Table III)

This factor was the time for the fuel to be seen on the external surface of the test article, as determined from film analysis. This time would be expected to be a function of the fire in the dry bay. At the very low dry bay ACPM, the initial external fuel spray time was significantly longer for JP-8 than for JP-4. This agrees with a previous conclusion, which showed that the fire duration for JP-8 was significantly longer at very low dry bay ACPM. At high ACPM, the spray time was independent of fuel type, although it tended to decrease for both fuels as ACPM increased and standoff distance decreased.

d. Time to Maximum Standoff Pressure (Table IV)

It is possible that the time to maximum standoff pressure is dependent on fuel type. Three cases show significance, but an evaluation of all cases as a whole does not prove a dependence on fuel type.

Of the 3 anomalous cases, two have a significantly larger F ratio. This explains the fact that the significant difference shown by the T value is masked by the corresponding F value.

e. Maximum Standoff Pressure Rise (Table V)

The maximum pressure in the dry bay was of major interest in the test program for assessing the difference between the two fuels. Eight cases show significance; in five of these, the higher pressures were obtained with JP-4. Data for these cases are as follows:

CASE No.	Test Description	Mean psi	
		JP-4	JP-8
2	(-,90,9,90,0,20)	23.1	10.2
7	(-,90,4,0,0,20)	25.0	11.9
11	(-,90,4,300,58,20)	4.5	6.1
18	(-,90,9,90,97,15)	6.6	12.3
20	(-,90,*,90,18,15)	1.1	1.5
27	(-,90,27,90,0,15)	33.7	2.7
28	(-,90,27,90,7,15)	11.7	1.7
30	(-,90,27H,90,4,15)	26.5	5.8

Case 20 may be eliminated because an overpressure of 1.5 psi should be within the capability of most aircraft structures. This case was a vapor shot with 10 PPI reticulated polyurethane foam in the fuel tank, and severe foam damage occurred during all three tests with JP-4; little foam damage occurred with JP-8. Of the remaining seven cases, JP-4 produced higher pressures in five, with a mean average overpressure of 18.7 psi, compared to 7.2 for JP-8.

Unfortunately, several cases had relatively high F values, which weakens the conclusion that JP-4 gives a statistically significant higher standoff pressure rise. Further analysis is required to resolve this.

Table VI presents the statistical results for the standoff overpressure for various combinations of the test conditions: Case 31 is a comparison of the two fuels for all test conditions. Case 32 considers all "Standard Tests" (i.e., all tests with the standoff on the front side, which excludes Cases 19 thru 26). Cases 33 through 37 are a breakdown of Case 32 by size of standoff.

Case 31 (all tests) shows that JP-4 having a higher overpressure than JP-8 is a significant result. Case 32 (Standard Tests) shows a significantly higher mean overpressure for JP-4, with only a 2.5% error possible, due to experimental chance. The remaining cases of Table VI indicated that for JP-4 the overpressure increased as the volume of the dry bay increased. This trend was not observed for JP-8.

TABLE VI  
MAXIMUM STANDOFF PRESSURE RISE FOR JP-4 vs. JP-8 FUEL (psi  $\times 10^3$ )

No.	Test Description	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			JP-4	JP-8	JP-4	JP-8				
31	All Tests	126	112	13,780	5,590	99	73	2.47	1.99**	1.65
32	Standard Tests only	105	91	14,395	5,424	118	85	2.65	2.25**	1.65 Sign. at 2.5% error
33	All 9" Standoff	55	42	9,094	7,996	113	104	1.14	.45	1.66 Front side only
34	All 4" Standoff	31	29	14,646	2,541	106	89	5.76	.69	1.67 Front side only
35	All 1" Standoff	8	8	16	234	6	21	14.6	2.64**	1.76 Front side only
36	All 27" Standoff	5	6	14,818	716	249	22	20.7	4.48**	1.83 Front side only
37	27" Standoff	6	6	35,939	2,285	268	86	15.7	2.28**	1.81 Hat section on front

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Value shows statistical difference

## SECTION V

## ANALYSIS OF TEST RESULTS

## 1. TEMPERATURE EFFECT ON STANDOFF OVERPRESSURE

An initial fuel temperature of 90°F was selected as the baseline temperature for the test program. The selection of this temperature was a trade-off between the most probable operational fuel temperature, and a temperature easily controlled in a test program. It is easier to heat fuel above ambient temperature than to cool it. In addition, we felt that the severity of the reactions for JP-8 would be less at lower temperatures, and those from JP-4 would be greater. To assess the effects that initial fuel temperature could have on the test results, we conducted several tests with both fuels at 75°F. The results of these tests are given in Table VII. There is no clear statistical evidence of the effect of fuel temperature on standoff overpressure for either fuel, although JP-4 tended to produce higher overpressures at the lower temperature. No trend was observed with JP-8.

## 2. TANK PRESSURE EFFECT ON STANDOFF OVERPRESSURE

A baseline initial fuel tank pressure of 20 psia was used during the first half of the program, based on the operational consideration that the positive pressure in the fuel tanks of most aircraft is in the range of 1-1/2 to 15 psi. About halfway through the test program, several tests were conducted at 15 psia and the results were compared, as shown in Table VIII. There is a clear indication that the standoff overpressure is not dependent on initial tank pressure for JP-4. Case 45 was significant, showing the lower initial tank pressure for JP-8 produced the higher standoff overpressure; case 44, however, indicated the reverse, although not at a significant level. Some unique cross-coupling between initial pressure and dry bay ACPM for JP-8 may have produced this result, although the test data was too limited to come to a definite conclusion. From an overall assessment of Table VIII, we conclude that no dependence of standoff overpressure on initial tank pressure was actually proven for either fuel. The second half of the program, however, was conducted at an initial fuel tank pressure of 15 psia.

TABLE VII  
TEMPERATURE EFFECT ON MAXIMUM STANDOFF PRESSURE RISE (psi  $\times 10^3$ )

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^{**}$	REMARKS
			75°F	90°F	75°F	90°F				
38	(4,75,9,90,23,20)	2			1800	102		2.07	1.84	1.94
	VS									
	(4,90,9,90,23,20)	6			870.4	54				
39	(4,75,9,90,96,20)	3			201	73				
	VS									
	(4,90,9,90,96,20)	6			369	61				
40	(8,75,9,90,23,20)	2			709	57				
	VS									
	(8,90,9,90,23,20)	5			1299	82				
41	(8,75,9,90,96,20)	2			516	96				
	VS									
	(8,90,9,90,96,20)	4			455	67				

\*  $T_c = T$  value at 95.0% {10% error - two tail}

TABLE VIII  
INITIAL TANK PRESSURE EFFECT ON MAXIMUM STANDOFF PRESSURE RISE (psi  $\times 10^3$ )

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )			MEAN ( $\bar{X}$ )	$F$	T	$T_c^*$	REMARKS
			15 psia	20 psia	15 psia					
42	(4,90,9,90,23,15)	4		120		58				
	vs. (4,90,9,90,23,20)			6						
43	(4,90,9,90,97,15)	3		36		66				
	vs. (4,90,9,90,97,20)			6		369				
44	(8,90,9,90,23,15)	4		260		57				
	vs. (8,90,9,90,23,20)			5		1299				
45	(8,90,9,90,97,15)	3		952		123				
	vs. (8,90,9,90,97,20)			4		455				

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Value shows statistical difference

### 3. EXTERNAL AIRFLOW EFFECT ON STANDOFF OVERPRESSURE

The amount of external airflow over the test article was not expected to affect the overpressure in the standoff. Eight cases (46 - 53) where direct comparisons could be made are shown in Table IX. The statistical results verify the expected results; however, the external airflow was expected to affect the degree and type of fire outside the test article. As noted in the Remarks, all sustained external fires occurred with no external airflow. A complete list of test conditions which produced sustained external fires is given below:

<u>TEST DESCRIPTION</u>	<u>NO. OF SUSTAINED EXTERNAL FIRES</u>
(4,90,9,90,0,20)	1
(4,90,9,0,0,20)	3
(4,90,4,90,75,20)	1
(4,90,1,0,0,20)	3
(4,100,1,0,0,20)	1
(4,90,0,90,0,20)-(no standoff)	2
(4,90,27,90,0,15)	1
(4,90,27,90,4,15)	1
(4,90,27,90,7,15)	2
(8,90,27,90,0,15)	2

Sustained external fires were defined as having a duration of two seconds or longer. In most cases beyond two seconds, it was impossible to determine whether the fire was being sustained by the fuel of the test article or the fuel on the pad. When a sustained fire was noted, it was standard test procedure to increase the external airflow to about 200 knots and wait 30 seconds, which extinguished the fire in about 50% of the cases. In the remaining cases, the Fire Department extinguished the fire after about 5 minutes elapsed time with zero airflow.

Out of a total of 34 tests with no external airflow, 7 resulted in sustained external fires; of 174 tests conducted with 90 knots external airflow, 10 sustained external fires; of 6 tests conducted at 125 knots and 38 tests conducted at 300 knots external airflow, none sustained external fires. From this we concluded that the probability of sustained external fires occurring outside the test article was reduced as external

TABLE IX  
EXTERNAL AIR FLOW EFFECTS ON MAXIMUM STANDOFF PRESSURE RISE (psi  $\times 10^3$ )

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )	MEAN ( $\bar{X}$ )	F Ratio	$T$	$T_c^*$	REMARKS
46	(4,90,9,0,0,20)	4	18244	229	1.02	0.32	1.86	$\bar{Z}$ S.E.F.** at 0 knots
	vs. (4,90,9,90,0,20)	6	18653	231				0 S.E.F. at 90 knots
47	(4,90,9,90,96,20)	5	369	61	4.5	0.31	1.81	0 S.E.F. at 90 knots
	vs. (4,90,9,300,101,20)	6	82	64				0 S.E.F. at 300 knots
48	(4,90,4,0,0,20)	6	21473	250	1.49	1.16	1.83	0 S.E.F. at 0 knots
	vs. (4,90,4,90,0,20)	5	31889	137				0 S.E.F. at 90 knots
49	(4,90,1,0,0,20)	3	17	5	4.7	1.66	2.01	3 S.E.F. at 0 knots
	vs. (4,90,1,90,0,20)	4	4	9				0 S.E.F. at 90 knots
50	(8,90,9,0,0,20)	5	2569	108	2.3	0.21	1.86	0 S.E.F. at 0 knots
	vs. (8,90,9,90,0,20)	5	1115	102				0 S.E.F. at 90 knots

TABLE IX (CONTINUED)

No.	Test Description a b c d e f	n	VARIANCE ( $\sigma^2$ )		MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
			vs.	(8,90,9,90,96,20)	4	455				
51	(8,90,9,300,101,20)	5			325		56			0 S.E.F. at 300 knots
52	(8,90,4,0,0,20)	6	vs.	(8,90,4,90,0,20)	6	3076	119	2.8	0.94	1.81
						1088	144			0 S.E.F. at 90 knots
53.	(8,90,1,0,0,20)	4	vs.	(8,90,1,90,0,20)	4	259	18	1.0	0.48	1.94
						268	24			0 S.E.F. at 90 knots

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* S.E.F. Sustained External Fire

airflow increased. It should be noted that out of a total of 133 tests with JP-4 fuel, 15 sustained external fires, whereas out of 119 tests with JP-8, only 2 sustained external fires.

#### 4. EFFECT OF VOID SPACE AIR CHANGES PER MINUTE ON STANDOFF OVERPRESSURE

The ACPM in the standoff was varied over a wide range of test conditions for both fuels. Results indicated the following.

For zero ACPM, the void space was essentially a sealed container. For the tests with a positive ACPM, the void space was modified to accept ram air from the external airflow and to dump the exit air overboard. Figures 5, 6, and 7 show the resulting void space overpressure as a function of ACFM for both JP-4 and JP-8 in four different test articles. The case numbers are shown for reference to test conditions presented previously. Some of the plotted points are a combination of cases, since the test conditions were similar except for the external airflow, and this, as indicated previously, had little effect on overpressure.

After reviewing these figures and considering the standard deviation ( $\sigma$ ), we determined that the conditions for the tests listed in Table X should be analyzed for statistical significance. Based on the information of Table X, we noted the following:

a. For JP-4 in the 9 inch standoff, there was a large decrease in overpressure at moderate ACPM (23 to 100) compared to that at zero ACPM. No positive comparative statement can be made for the high ACPM (325).

b. For JP-8 in the 9 inch standoff, there was a small decrease in overpressure at moderate ACPM (~100) compared to that at zero ACPM. The maximum overpressure occurred at the high ACPM (325).

c. In the 4 inch standoff, both JP-4 and JP-8 experienced a decrease in overpressure at moderate ACPM (18 to 180) compared to that at zero ACPM.

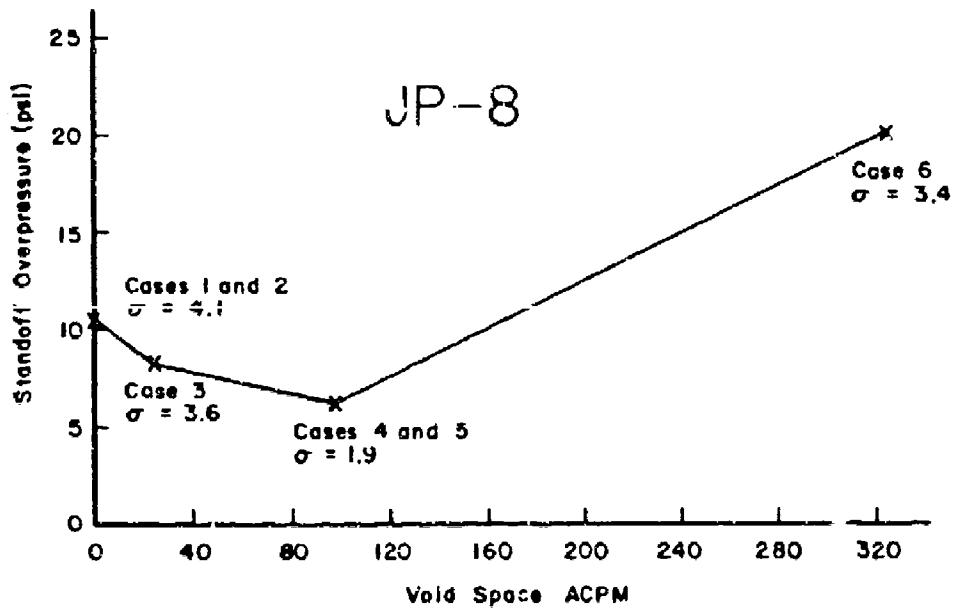
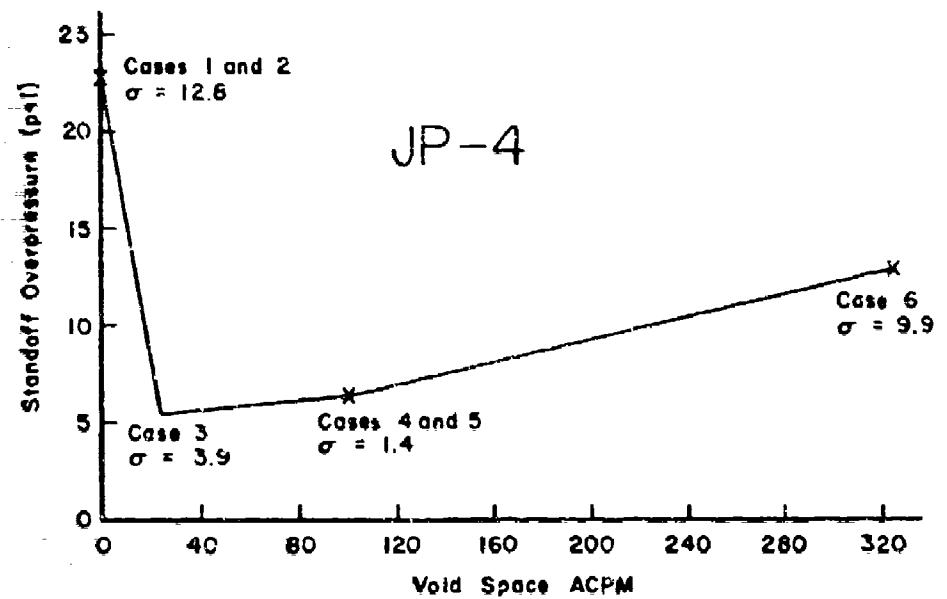


Figure 5. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 9-Inch Standoff

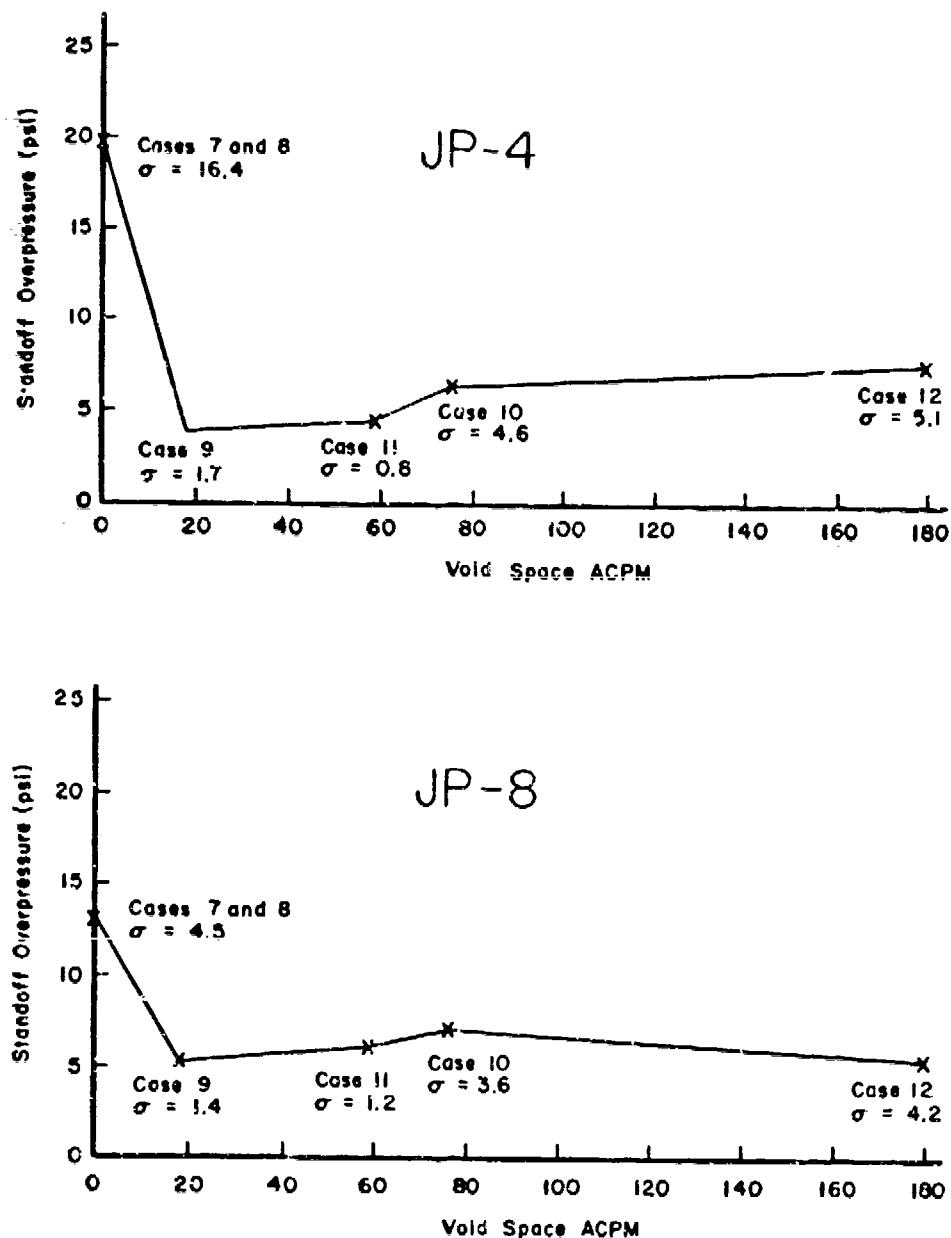


Figure 6. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 4-Inch Standoff

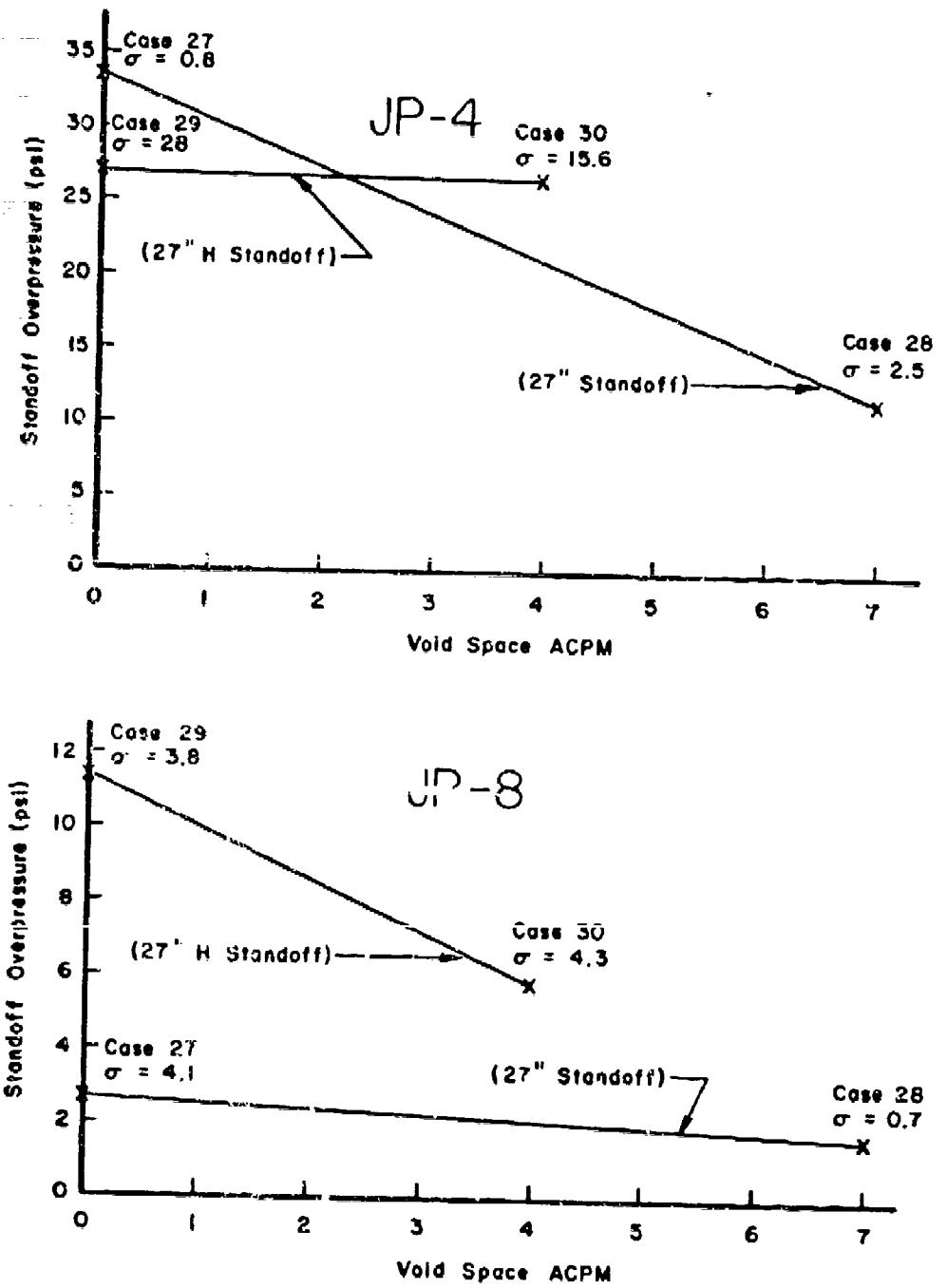


Figure 7. Overpressure vs. ACPM for JP-4 and JP-8 Fuels in 27-Inch and 27H Standoff

TABLE X  
EFFECT OF ACPM ON MAXIMUM STANDOFF PRESSURE RISE  
(psi  $\times 10^2$ )

No.	Test Description	n	VARIANCE ( $\sigma^2$ )	MEAN ( $\bar{X}$ )	F Ratio	T	$T_c^*$	REMARKS
54	JP4, Cases 1&2 vs 3	10	6	16446	870	231	54	18.9
55	JP4, Cases 1&2 vs 4&5	10	12	16446	207	231	62	79.4
56	JP4, Cases 1&2 vs 6	10	6	16446	9855	231	129	1.7
57	JP8, Cases 1&2 vs 4&5	10	9	1649	364	105	61	4.5
58	JP8, Cases 1&2 vs 6	10	3	1646	1185	105	201	1.4
59	JP8, Cases 4&5 vs 6	9	3	364	1185	61	201	3.3
60	JP4, Cases 7&8 vs 9	11	6	26985	306	199	40	86.3
61	JP8, Cases 7&8 vs 9	12	5	2059	190	132	52	10.8
62	JP4, Case 27 vs 28	3	2	69	612	337	117	8.8
63	JP8, Case 29 vs 30	3	3	1460	1873	114	58	1.3
								1.69
								2.13

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Value shows statistical difference

d. In the 27 inch standoff, JP-4 experienced a large decrease in overpressure with small ACPM compared to that at zero ACPM, but in the 27 inch H Standoff experienced no difference between small ACPM and zero ACPM.

e. In the 27 inch and 27 inch H standoffs, JP-8 experienced no significant difference between zero ACPM and the small ACPM.

The foregoing statements apply to specific tank configurations and therefore are of little general value. We attempted to obtain more information by assuming that the amount of fuel entering the dry bay was to some degree independent of tank configuration, and that the volume of airflow in the dry bay determined the size of the flammability region and therefore the overpressure. Figure 8 gives the results of the effort and Table XI the statistical information. This analysis provided little additional insight, although it showed that at an airflow of 60 to 80 ft<sup>3</sup>/min, JP-4 reached a peak of overpressure whereas JP-8 hit a minimum. These airflows should be considered in any additional testing to determine the effect of airflow on dry bay overpressure.

## 5. DAMAGE POTENTIAL

Considering standoff overpressure as the critical parameter for comparing the two fuels was predicated on potential damage to the aircraft structure and danger of implosion of a fuel tank. In general, fuel tanks are designed to withstand a higher internal than external overpressure. Figure 9 was developed for the "Standard Test Conditions" to show the probability of a given overpressure or greater occurring as a function of overpressure. As may be seen, the probability of JP-4 is higher than for JP-8, particularly in the range of 10 to 40 psi. This figure, however, does not tell the complete story; the first step in arriving at a Total Damage Potential term requires that the probability distribution for the standoff overpressure for each fuel be established. Figure 10 gives the probability distribution developed from a histogram of the test data. By definition, the total probability must be unity, therefore the area for the two fuels must be equal.

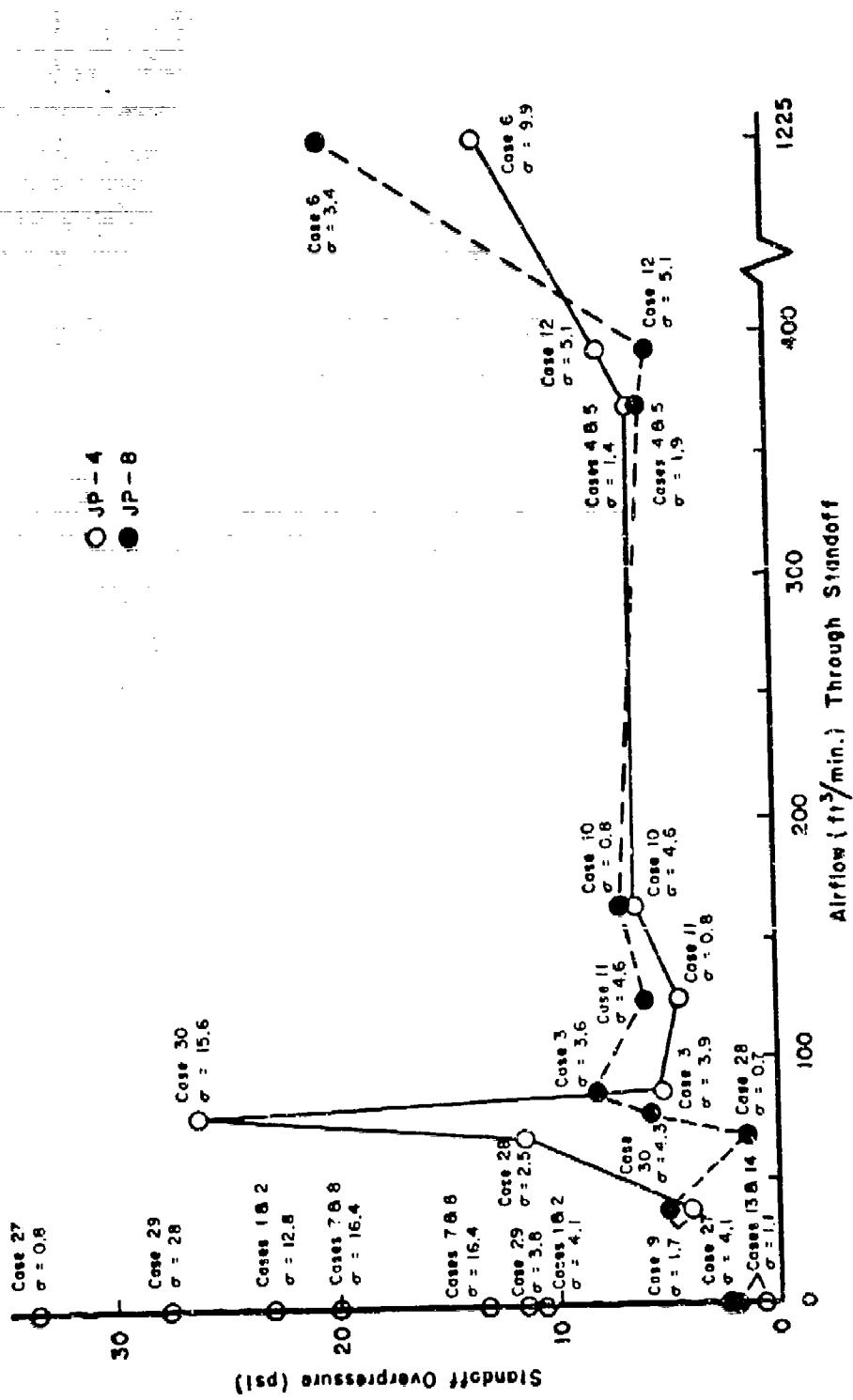


Figure 8. Overpressure vs. Air Flow in Standoff

TABLE XI  
AIR FLOW EFFECT ON MAXIMUM STANDOFF PRESSURE RISE

No.	Test Description	n	VARIANCE ( $\sigma^2$ )	MEAN ( $\bar{X}$ )		F Ratio	T	$T_c^*$	REMARKS
				1	2				
64	JP4, Cases 1&2 vs 7&8	10	11	16446	26985	231	199	1.6	0.77
65	JP4, Cases 7&8 vs 13&14	11	7	26985	12	199	7	2285.	3.06**
66	JP4, Cases 1&2 vs 27	10	3	16445	69	231	337	237.2	1.40
67	JP4, Case 27 vs 29	3	3	69	78525	337	271	1134.	0.58
68	JP4, Case 3 vs 9	6	6	870	306	54	40	2.9	1.04
69	JP4, Case 9 vs 28	6	2	306	613	40	117	2.0	4.99**
70	JP4, Case 28 vs 30	2	3	612	11191	117	256	18.3	1.86
71	JP8, Cases 1&2 vs 7&8	10	12	1646	2059	105	132	1.3	1.44
72	JP8, Cases 7&8 vs 13&14	12	8	2059	234	132	21	8.8	6.62**
73	JP8, Cases 1&2 vs 27	10	3	1646	1669	105	27	1.0	3.41**
74	JP8, Case 27 vs 29	3	3	1669	1460	27	114	1.1	3.82**
75	JP8, Case 3 vs 9	5	5	1299	190	82	52	6.8	1.75
76	JP8, Case 9 vs 28	5	3	190	50	52	17	3.8	3.96**
77	JP8, Case 28 vs 30	3	3	1873	50	58	17	37.2	1.61
									2.13

\*  $T_c = T$  value at 95.0% (10% error - two tail)

\*\* Values show statistical difference

Since the force acting on a surface that tends to produce failure is proportional to the overpressure, a Damage Potential term ( $DP_{\Delta P}$ ) may be defined for each overpressure. The point to be made here is that a high overpressure will result in more damage to the aircraft than a smaller overpressure. With this assumption,  $DP_{\Delta P}$  was defined as  $P_r \Delta P$ , and the results are shown on Figure 11. A total Damage Potential may then be defined as a function of safe overpressure; the safe overpressure is dependent on the design of a particular tank and is defined as the pressure below which no damage occurs. The total Damage Potential (TDP) therefore is:

$$TDP = \sum_{\Delta P_{Safe}} \frac{\Delta P_w}{DP_{\Delta P}} \text{ or } \sum_{\Delta P_{Safe}} \frac{\Delta P_w}{P_r \Delta P}$$

The results of this calculation are shown in Figure 12. JP-4 has a higher potential for damage than does JP-8, which was verified by the test article damage experienced during the test program.

The ratio of percentage of damage to the test article by JP-4 vs. that by JP-8, as given in Table XII, was 2.39. The ratio of area under the curves of Figure 12 for the two fuels was 2.45. The closeness of this comparison was somewhat surprising. Although there is no absolute measure for damage potential, these results should give a good relative measure for the two fuels.

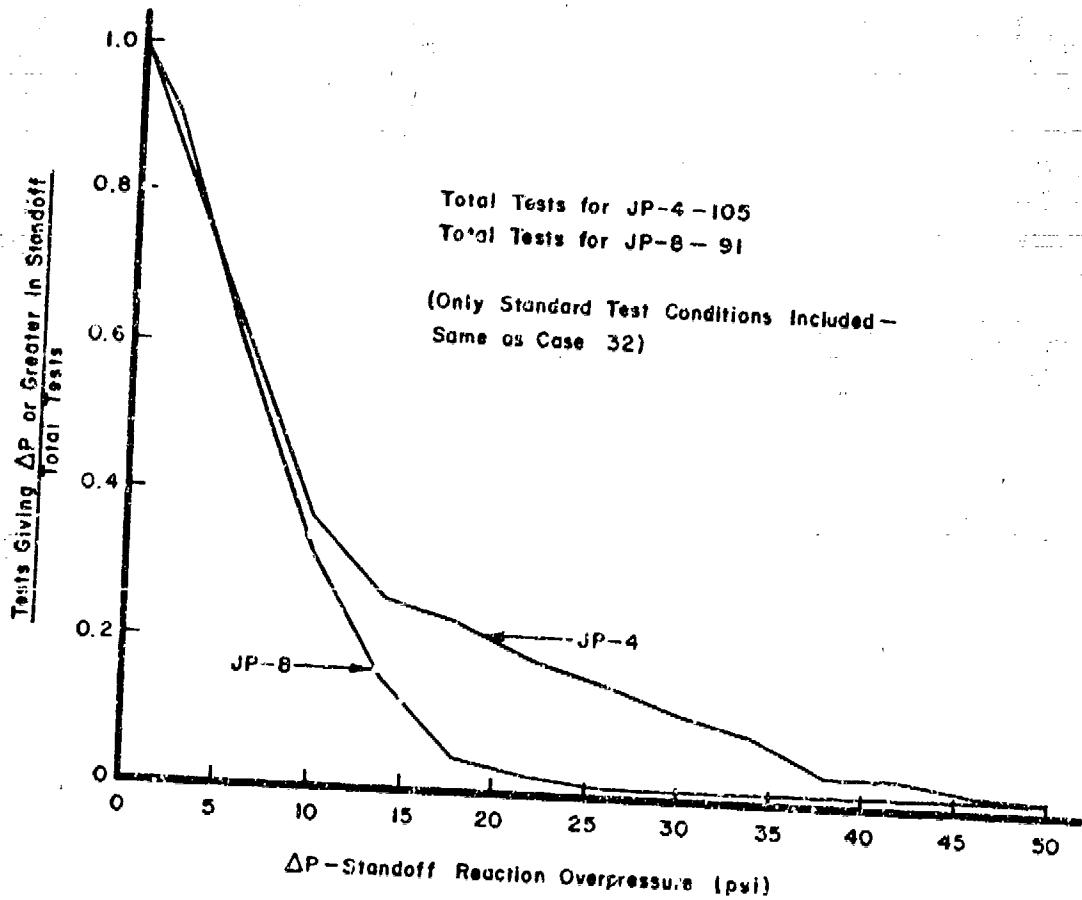


Figure 9. Probability of a Given Overpressure or Greater Occurring

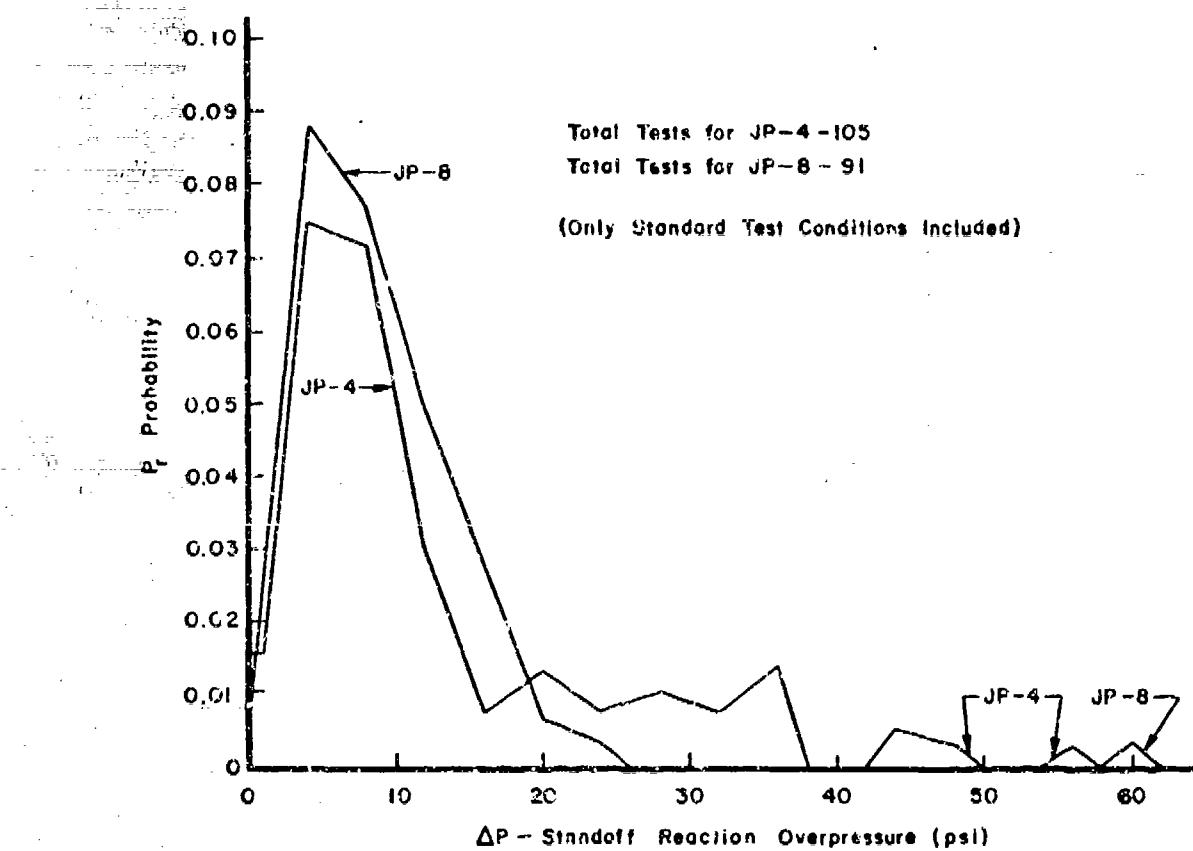


Figure 10. Probability Distribution for Standoff Overpressure

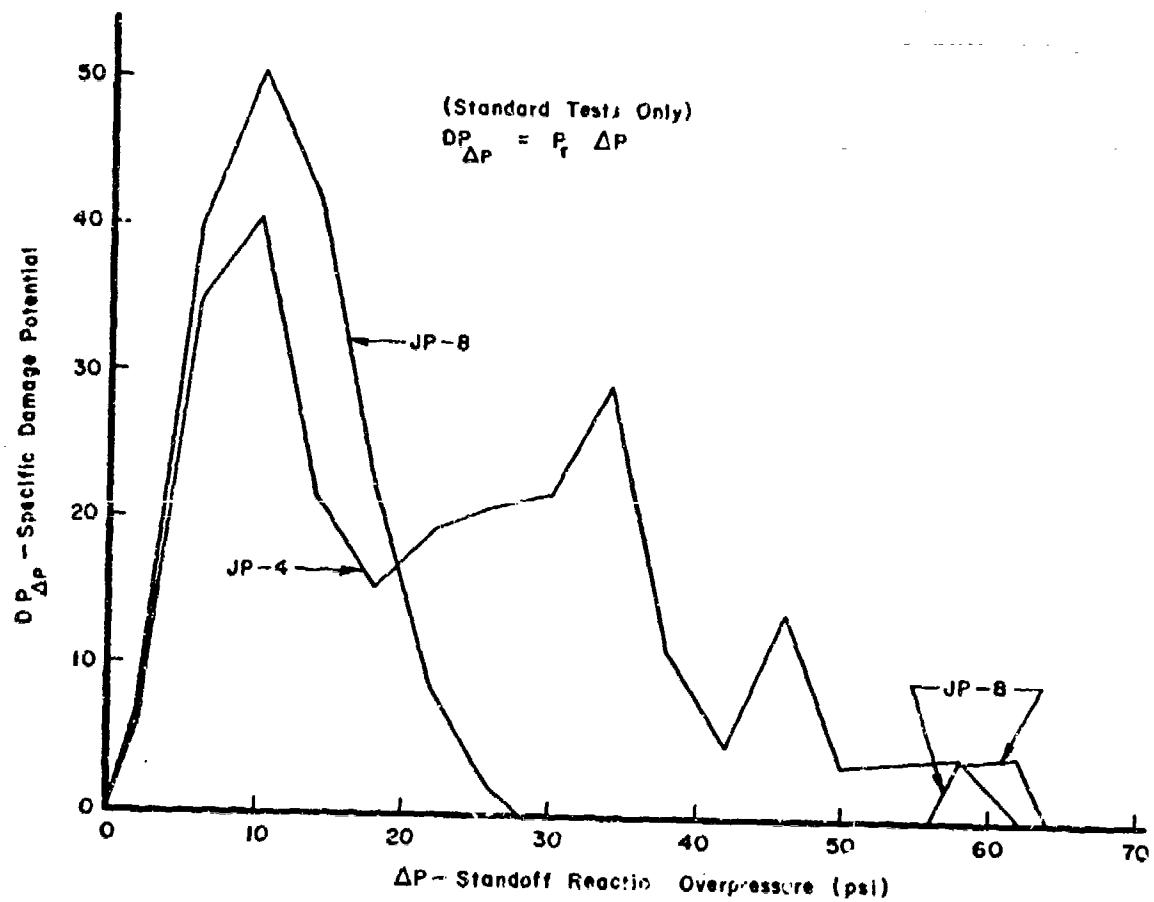


Figure 11. Specific Damage Potential for Each Standoff Overpressure

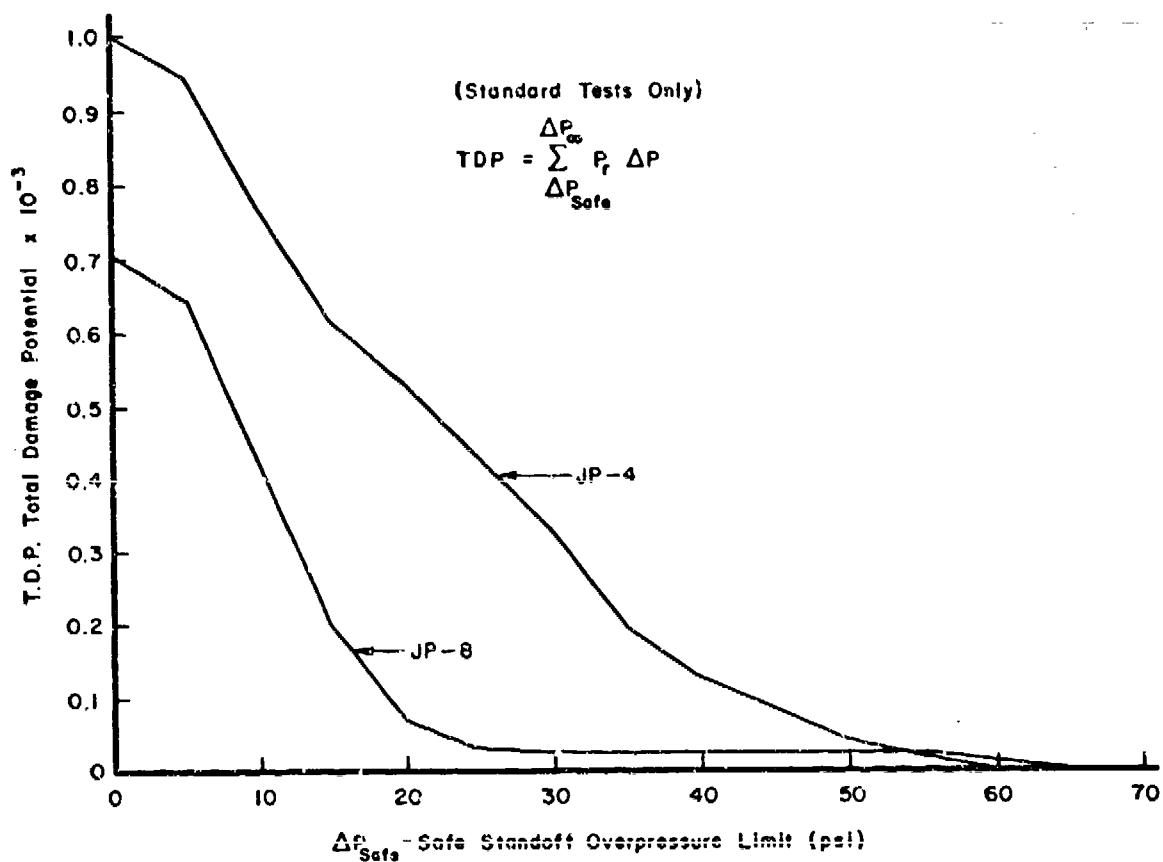


Figure 12. Total Damage Potential vs. Safe Standoff Overpressure Limit

## 6. OTHER FACTORS

Table XII summarizes results for factors not previously discussed. Of particular interest is that twice as many external flash fires occurred with JP-8 than with JP-4, whereas over six times as many sustained external fires occurred with JP-4.

Although all the test articles were constructed of heavy gauge steel and were designed for repeated gunfire testing, several failures did occur. There was a significantly larger number of tank failures associated with the JP-4 shots than with JP-8. These failures (16 with the JP-4 and 6 with JP-8) included blowing off the strike-plate, (which is equivalent to failure of the external skin of the aircraft), broken tank pressurization line, failure of the void space exhaust ventilation tube, and structural damage to the basic test article.

Another factor not discussed previously was the pressure rise in the fuel tank. No overpressure was observed for either fuel due to a fuel reaction inside the fuel tank; this was expected due to the design of the experimental program. This is not to say that no overpressures were measured in the fuel tank, but that the overpressures measured resulted from projectile dynamics and not from fuel reactions, as expected. The statistical results for the fuel tank overpressure are as follows:

	<u>JP-4</u>	<u>JP-8</u>
No. of Tests	105	89
Mean Overpressure (psi)	2.61	2.29
Variance (psi)	39.1	20.4
F ratio	1.91	
T value	0.40	

TABLE XII  
SUMMATION OF RESULTS

	JP-8	JP-4		
	Test	%	Test	%
Total Number of Tests	119		133	
Tests With Unknown or Unrecorded External Fires	0	0.00	0	0.00
Tests That Result in No External Fire	102	85.71	110	82.71
Summation of Flash, And Flash And Pit Fires (Less Than 2 Seconds)	15	12.61	8	6.02
Summation of Sustained Fires, Delayed Fires, And Fires And Explosions	2	1.68	15	11.28
<hr/>				
Tests That Resulted in External Fires				
Flash Fire (Less Than 2 Seconds)	15	12.61	8	6.02
Flash And Pit Fire	0	0.00	0	0.00
Delayed Fire	0	0.00	0	0.00
Fire And Explosion	0	0.00	0	0.00
Sustained Fire (Greater Than 2 Seconds)	2	1.68	15	11.28
<hr/>				
Tests That Resulted in Internal Fires				
Unknown Internal Reaction	13	10.92	8	6.02
No Internal Reaction	17	14.29	18	13.53
Reaction In Fuel Tank Only	0	0.00	0	0.00
Reaction In The Entrance Standoff	83	69.75	105	78.95
Reaction In The Standoff + Fuel Tank	2	1.68	1	.75
Reaction In The Exit Standoff	4	3.36	1	.75
Reaction In The Exit Standoff + Fuel Tank	0	0.00	0	0.00
Test Article Damage	6	5.04	16	12.03

SECTION VI  
CONCLUSIONS

1. At very low dry bay ACPM, the standoff fire duration was longer for JP-8 than for JP-4. There was no clear difference between the two fuels at high ACPM.
2. The incendiary burn time of the CAL .50 API was not affected by fuel type.
3. At very low dry bay ACPM, the time for the JP-8 fuel to be seen on the external surface of the test article was longer than for JP-4. At high ACPM the time was independent of fuel type.
4. The time to maximum standoff overpressure was independent of fuel type.
5. Thirty different sets of test conditions were evaluated for each fuel, and in 7 of these a significant difference occurred in the standoff overpressure between the two fuels. For these seven cases, JP-4 had a mean value of 18.7 psi as compared to 7.2 psi for JP-8.
6. For the "Standard Tests" (i.e., all tests with the standoff on the front side) JP-4 gave higher standoff overpressure than JP-8 at the 97.5% confidence level. The mean value was 11.8 psi for JP-4 and 8.5 psi for JP-8.
7. For the vapor shots with 10 ppi reticulated polyurethane foam in the fuel tank, severe foam damage occurred with all three JP-4 tests, whereas little damage occurred with the three JP-8 tests.
8. The effectiveness of 10 ppi reticulated polyurethane foam in the 4-inch standoff in preventing dry bay overpressure and fire was the same for both fuels.

9. The fire and dry bay overpressure conditions were more severe when the dry bay was located on the entrance side than on the exit side. This was true for both fuels. As the distance the projectile traveled in the fuel prior to impacting the exit dry bay increased, the amount of fire and overpressure decreased. During all tests in this program, maximum incendiary action occurred at initial projectile impact; therefore the vulnerability of exit dry bays requires additional investigation.
10. There was no clear statistical proof of the dependence of standoff overpressure on fuel temperature (75°F vs. 90°F) for either fuel, although a trend was indicated for JP-4 to produce higher overpressures at lower temperature.
11. No dependence of standoff overpressure on initial tank pressure (15 psia vs. 20 psia) was proven for either fuel.
12. Although some information was generated on the effect of dry bay ACPM on overpressure for specific test articles, no general conclusions were established.
13. An analysis of the standoff overpressures showed that, on the average, the damage potential of JP-4 was 2.45 times that of JP-8. Actual test article damage experience during the test program resulted in a value of 2.39.
14. Sustained external fires occurred in 11.28% of the tests with JP-4 and in only 1.68% for JP-8.
15. The general conclusion of this program was that JP-8 is less susceptible to fire and explosion induced by gunfire and structural damage should be less than that with JP-4. Many other factors, however, must be considered in the determination of the overall desirability of JP-8. A report on this subject is planned for the near future.

**APPENDIX I**  
**TEST RESULTS**

The following codes were used in the test results given in this appendix.

<u>CODE</u>	<u>DEFINITION</u>
2	TYPE OF TEST
2	STATIC TEST WITH AIR VELOCITY (FAA TEST)
	TYPE OF FUEL
400	JP4
800	JP8 (118 DEG FLASH)
	TANK TYPE
30	FAA TANK-30 GAL (27 IN. STANDOFF AT ENTRANCE)
31	FAA TANK-30 GAL (27 IN. STANDOFF AT EXIT)
32	FAA TANK-30 GAL (27 IN. STANDOFF AT ENTRANCE WITH 10 CU. FT. HAT SECTION)
80	FAA TANK-80 GAL (9 IN. STANDOFF AT ENTRANCE)
81	FAA TANK-80 GAL (9 IN. STANDOFF AT EXIT)
106	FAA TANK-106 GAL (4 IN. STANDOFF AT ENTRANCE)
130	FAA TANK-130 GAL (1 IN. STANDOFF AT ENTRANCE)
135	FAA TANK-135 GAL (NO DRY BAY)
	TRAJECTORY PHASES
11	VAPOR
22	LIQUID
	SECOND TEMPERATURE
*	TYPE 2 TEST - AMBIENT AIR TEMPERATURE
	FUEL AND SECOND TEMPERATURE
*	INDICATES TEMPERATURE APPROXIMATE
	STRIKER PLATE TYPE
42	2024-T3 ALUMINUM
73	2024-T3 ALUMINUM + 10PPI EXTERNAL FOAM
	PROJECTILE TYPE
53	50 CAL. API
	PROJECTILE VELOCITY
*	INDICATES VELOCITY APPROXIMATE
	TANK FILLER
100	NONE
200	R.P. FOAM 10 PPI

<u>CODE</u>	<u>DEFINITION</u>
1	EXTERNAL FIRE TYPES (FIRE TYPE)
2	NO FIRE
3	FLASH FIRE (LESS THAN 2 SECONDS)
4	SUSTAINED FIRE
5	DELAYED FIRE
6	FLASH AND PIT FIRE
7	FIRE AND EXPLOSION
	UNKNOWN REACTION
-1	INITIAL TANK PRESSURE (PSIA) INDICATES UNKNOWN INITIAL TANK PRESSURE
-1	MAIN TANK PRESSURE RISE (PSI) INDICATES UNKNOWN PRESSURE RISE
	TIME TO MAXIMUM PRESSURE RISE MAIN TANK (SECONDS x 100) INDICATES UNKNOWN TIME TO MAXIMUM PRESSURE RISE
1	INTERNAL REACTION (INT REA)
2	UNKNOWN REACTION
3	NO REACTION
4	FUEL TANK REACTION
5	ENTRANCE STANDOFF REACTION
6	ENTRANCE STANDOFF & FUEL TANK REACTION
7	EXIT STANDOFF REACTION
8	EXIT STANDOFF & FUEL TANK REACTION
	LARGE SUSTAINED FIRE (GREATER THAN 2 SECONDS)
-1	CRITERIA I INDICATES UNKNOWN CRITERIA VALUE
	INCENDIARY FUNCTION
1	STANDOFF (YES) TANK (YES) EXTERNAL (YES)
2	STANDOFF (YES) TANK (YES) EXTERNAL (NO)
3	STANDOFF (YES) TANK (NO) EXTERNAL (YES)
4	STANDOFF (YES) TANK (NO) EXTERNAL (NO)
5	STANDOFF (NO) TANK (NO) EXTERNAL (NO)
6	STANDOFF (NO) TANK (NO) EXTERNAL (NO)
7	STANDOFF (NO) TANK (YES) EXTERNAL (YES)
8	STANDOFF (NO) TANK (YES) EXTERNAL (NO)
9	NO STANDOFF TANK (NO) EXTERNAL (YES)
2	SPECIAL TEST CONDITIONS STATIC TEST WITH AIR FLOW
21	ULLAGE ATMOSPHERE NORMAL AIR
-1	CRITERIA II INDICATES UNKNOWN CRITERIA VALUE STANDOFF FIRE DURATION (MILLISECONDS)

<u>CODE</u>	<u>DEFINITION</u>
	CRITERIA III
-1	INDICATES UNKNOWN CRITERIA VALUE INCENDIARY BURN TIME (MILLISECONDS)
	CRITERIA IV
-1	INDICATES UNKNOWN CRITERIA VALUE INITIAL EXTERNAL FUEL SPRAY TIME (MILLISECONDS)
-3	NO INITIAL EXT. FUEL SPRAY
	CRITERIA V
-1	INDICATES UNKNOWN CRITERIA VALUE TIME TO MAXIMUM STANDOFF PRESSURE RISE (MILLISECONDS)
	CRITERIA VI
-1	INDICATES UNKNOWN CRITERIA VALUE MAXIMUM STANDOFF PRESSURE RISE (PSI x 10)
	CRITERIA VII
-1	INDICATES UNKNOWN CRITERIA VALUE SECONDARY STANDOFF PRESSURE RISE (PSI x 10)
	CRITERIA VIII
-1	INDICATES UNKNOWN CRITERIA VALUE TIME TO SECONDARY STANDOFF PRESSURE RISE (MILLISECONDS)
	CRITERIA IX
-1	INDICATES UNKNOWN CRITERIA VALUE VOID SPACE AIR CHANGES (CHANGES/MIN)
	CRITERIA X
-1	INDICATES UNKNOWN CRITERIA VALUE AIR VELOCITY (FT/SECOND)

This Document  
Reproduced From  
Best Available Copy

## TEST CONDITIONS AND RESULTS

PROJECTILE FILL FIRE TANK PRESSURE TEST CRIT * SEE TEST TYPE FUEL TEMP TEND (STOKE - PLATE) SPACE ANGLE (TYPE VEL, TYPE TYPE PRES RISE MAX P REA I DATA NO TEST TYPE FUEL (FEC) (FEC) (FEC) (FEC) (FEC) (FEC) (FEC) (FEC) (PSI) (PSI) (PSI) S=100)									
TEST	SPEC CAPT HLL	MOTR CRTR RATT	RATT	CRIT	CRIT	CRIT	FUEL	CRIT	CRIT
NO	TEST	II ATMO	V	V	V	V	OFSTW	IX	X
11	2	400 60 60.0	77	90	70*	42	+215	0.30	10
11	2	162 21	46	670	19				
12	2	600 90 60.1	72	21	72*	42	+215	0.31	13
12	2	44 21	14	10	16				
13	2	A11 80 60.3	72	92	71*	42	+215	0.00	30
13	2	97+ 21	7	1142	94				
14	2	900 90 60.1	72	92	75*	42	+215	0.01	30
14	2	542+ 21	1P	1420	111				
15	2	430 40 61.0	22	04	42*	42	+215	0.01	70
15	2	519 21	16	1170	74				
15	2	410 40 60.0	22	05	42*	42	+215	0.00	30
15	2	576+ 21	48	1124	92				
17	2	470 90 60.0	72	95	85*	42	+215	0.00	30
17	2	405 21	1E	1212	142				
19	2	430 40 60.0	22	94	77*	42	+215	0.01	70
19	2	511 21	74	960	74				
20	2	400 90 60.1	22	49	67*	42	+215	0.01	10
21	2	199 21	54	714	45				



TEST NO.	TEST TYPE	FUEL	TANK	FUEL TEMP	TEMP (°F)	TYPE	TYPE	VOL	DIA	THICK	ANGLE (deg)	PROJECTILE	SHEET	CRIT	TIME	PRESSURE	TYPE	PRES	QSF	TYP	MAX P	RFA	DATA	(PSI) (SPLU)	(FDS)	
71	2	400	106	80.0	72	95	55	2	.215	6.00	10	53	2400*	100	2	200.0	1.4	-1	4	3	*	*	*	*	*	*
31	2	11	21	66	99	93						211	0	0	0	14.0	0	0	0	0	0	0	0	0	0	0
12	2	400	106	80.0	72	95	96	62	.215	6.33	11	53	2400*	130	1	200.0	1.4	-1	4	3	*	*	*	*	*	*
13	2	400	106	80.0	72	95	50	43	.215	6.00	10	53	2400*	100	1	200.0	2.0	2.0	3	*	*	*	*	*	*	
17	2	454	21	34	94	94						129	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
14	2	400	106	80.0	72	92	51	42	.215	6.00	11	53	2400*	100	1	200.0	2.2	-1	4	3	*	*	*	*	*	*
34	2	191	21	74	99	97						102	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
35	2	400	106	80.0	72	95	95	62	.215	6.00	12	53	2400*	100	1	200.0	1.4	-1	3	*	*	*	*	*	*	
35	2	112	21	92	920	99						117	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
15	2	400	106	80.0	72	95	97	62	.215	6.00	10	53	2400*	100	1	200.0	2.0	-1	4	3	*	*	*	*	*	*
37	2	400	106	80.0	72	90	51*	42	.215	6.00	10	53	2400*	100	1	200.0	1.4	-1	4	3	*	*	*	*	*	*
36	2	400	106	80.0	72	90	65*	43	.215	6.00	10	53	2400*	100	1	200.0	2.5	-1	4	3	*	*	*	*	*	*
36	2	16	21	74	97	94						21	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
37	2	19	21	95	95	104						21	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
37	2	195	21	31	90	94						214	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
40	2	400	106	80.0	72	90	71*	42	.215	6.00	10	53	2400*	100	1	200.0	1.6	-1	4	3	*	*	*	*	*	*
39	2	195	21	96	94	21						420	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0
40	2	24	21	96	94	21						420	0	0	14.0	0	0	0	0	0	0	0	0	0	0	0



TEST NO.	TYPE	FUEL TANK VUL.	FUEL TANK TYPE	THICKNESS	SPACE ANGLE	ANGLE (DEG)	ANGLE (DEG)	PLATE	STOKED	INERTIAL	FILL TIME	TANK PRESSURE	RISE RATE	MAX P. REA	CRT	SE	DATA SHEET		
51	2	410	106	40.7	22	0.0	61°	42	.215	4.03	1.0	53	2400*	103	1	2.3	-1.4	3	
51	2	376	21	0	954	27						176	0	0	18.0	0	0	152	
52	?	400	106	40.7	22	90	47°	42	.215	4.03	10	53	2400*	100	1	20.0	2.0	-1.4	3
52	?	267	21	0	709	71						174	0	0	18.0	0	0	152	
53	2	400	106	40.0	22	30	47°	42	.215	4.03	30	53	2400*	100	2	20.0	2.3	-1.4	3
53	2	263	21	0	709	71						132	0	0	18.0	0	0	152	
54	2	400	106	40.0	22	30	47°	42	.215	4.03	30	53	2400*	100	1	20.0	2.7	-1.4	3
54	2	263	21	0	473	-1						166	0	0	18.0	0	0	152	
55	2	400	106	40.0	22	107*	40°	42	.215	1.00	10	53	2400*	100	3	20.0	1.2	-1.4	3
55	2	-1	21	72	7	-1						3	0	0	18.0	0	0	0	
56	2	400	106	40.0	40	47	0.715	1.03	10			53	2400*	100	1	20.0	-1.0	-1.4	3
56	2	-1	21	76	76	-1						-1	0	0	14.0	0	0	0	
57	2	400	106	40.0	22	47	40	42	.215	1.03	10	53	2400*	100	3	20.0	.4	-1.4	3
57	2	-1	21	72	0	-1						6	0	0	14.0	0	0	0	
58	2	400	106	40.0	22	107*	40°	42	.215	1.03	10	53	2400*	100	7	20.0	.4	-1.4	3
59	2	410	130	40.0	22	10	37°	47	.215	1.03	10	53	2400*	103	3	20.0	0.0	-1.4	3
59	2	-1	21	76	76	0	-1					0	0	3	14.0	0	0	0	
60	2	410	130	40.0	22	97	97	42	.215	1.03	30	53	2400*	103	1	20.0	0.0	-1.4	3
60	2	-1	21	76	76	0	-1					6	0	3	14.0	0	0	152	

02/16/72		TEST TYPE		FUEL TANK	FUEL TRAJ	TEMP	(ST9KFP)	-- PLATE	(PROJECTILE)	FILL FIRE	TANK PRESSURE	TIME	CRT	* SEE						
NO	TEST	TYPE	TYPE	FUEL	THICK	TYPE	ANGLE	TYPE	VFL	TYPE	PRES	RISE	MAX P	DATA						
				GAL)	(IN)	(IN)	(IN)	(IN)	(IN)	(FDS)	(PSIA)	(PSI)	(S=100)	SHEET						
51	2	430	170	93.7	32	90	7A	.42	.215	1.00	10	53	2400*	100	2	20.0	.8	-1	4	3
51	2	-1	21	1F	5A	-1				10	0	0	10.0				0	0	152	
52	2	400	170	94.0	22	95	40	.42	.215	1.00	30	53	2400*	130	1	20.0	.4	-1	4	-1
52	2	-1	21	-1	-1	-1				9	0	0	10.0				0	0	152	
53	2	400	170	94.1	22	90	45	.42	.215	1.00	10	53	2400*	100	1	20.0	0.0	-1	4	1
53	2	-1	21	1	50	-1				10	0	0	10.0				0	0	152	
54	2	400	170	94.1	22	95	40*	.42	.215	1.00	30	53	2400*	100	2	20.0	.5	-1	1	3
54	2	-1	21	1F	7A	-1				35	0	0	10.0				0	0	152	
55	2	400	170	94.1	22	95	40*	.42	.215	1.00	20	53	2400*	100	1	20.0	.4	-1	4	3
55	2	-1	21	1F	7A	-1				4	0	0	10.0				0	0	152	
56	2	400	170	94.1	22	95	32*	.42	.215	1.00	10	53	2400*	100	2	20.0	.4	-1	1	3
56	2	-1	21	1C	7A	-1				24	0	0	10.0				0	0	152	
57	2	400	170	94.1	22	90	7A*	.42	.215	1.00	20	53	2400*	100	2	20.0	-1.0	-1	4	3
57	2	-1	21	7A	6A	-1				6	0	0	10.0				0	0	152	
58	2	400	170	94.1	22	90	33*	.42	.215	1.00	30	53	2400*	101	1	20.0	.4	-1	4	3
58	2	-1	21	7A	7A	-1				39	0	0	10.0				0	0	152	
59	2	400	170	94.0	22	90	33*	.42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	3
59	2	-1	21	7A	7A	-1				23	0	0	10.0				0	0	152	
60	2	400	170	94.1	22	90	7A*	.42	.215	1.00	30	53	2400*	100	1	20.0	.4	-1	4	3
60	2	-1	21	7A	7A	-1				6	0	0	10.0				0	0	152	

\* FIRE SHOT OUT PENETRATION HOLE REMAINED ON EDGE OF TEST PAD BUT DID NOT FLASH BACK TO JETE TANK SPILLAGE

TEST	TYPE	FUEL	VOL J	WEIGHT	TANK TWO	(STATE)	SPACER THICK	ANGLE	PROJECTILE	FILL	FIRE	PRESS TIME	INT CRIT	* SEE	
NO	TEST TYPE	TYPE	VOL	WEIGHT	FUEL TWO	(TYPE)	THICK	ANGLE	VEH	TYPE	TYPE	MAX PULSE	DATA	I SHEET	
TEST	NO	TEST	TYPE	WEIGHT	(GAL)	(MFG F)	(NEC E)	(IN)	(IN)	(IN)	(IN)	(PSIA)	(PSI)	(PSIA) (PSI)	
71	2	900	1.0	94.0	22	95	324	4?	.215	1.031	20	53	2400*	100 1 20.0 .7 -1 4 3	
71	2	744+	21		2	252	-1			28	0	0	19.0	0	152
72	2	400	1.0	94.0	22	95	33*	42	.215	1.04	70	53	2400*	100 1 20.0 0.0 -1 4 3	
72	2	-1	21		?	66	-1			3	0	0	19.0	0	152
73	2	490	0.0	60.0	??	98	42*	4?	.215	0.93	30	53	2400*	100 1 15.0 0.0 -1 4 3	
73	2	340	21		10	-1	48			56	52	7	19.0	0	152
74	2	400	0	60.0	??	90	64*	4?	.215	0.00	30	53	2400*	100 1 20.0 0.0 -1 4 3	
74	2	747	21		7	40	78			94	48	10	18.0	0	152
75	2	400	0	60.0	22	95	60*	42	.215	0.00	10	53	2400*	100 1 20.0 0.0 -1 4 3	
75	2	343	21		6	47	7			46	0	0	18.0	0	152
76	2	400	0	60.0	22	56	64*	24		53	2400*	100 1 20.0 0.0 -1 4 3			
76	2	707	21		7	-1	-1			0	0	0	18.0	0	152
77	2	400	0	60.0	??	95	40*	4?	.215	0.00	20	53	2400*	100 1 20.0 0.0 -1 4 3	
77	2	232	-1		11	-1	76			60	0	0	18.0	0	152
78	2	410	0	60.0	??	90	49*	4?	.215	0.00	10	53	2400*	100 1 20.0 0.0 -1 4 3	
78	2	742	21		11	264	20			60	0	0	18.0	0	152
79	2	400	0	60.0	??	90	49*	4?	.215	0.00	10	53	2400*	100 1 15.0 0.0 -1 4 3	
79	2	257	21		6	-1	21			40	0	0	16.0	0	152

12/16/72 TEST TYPE FUEL TANK TEMP TEMP (STANDOFF) PLATE 1 (PROJECTILE) FILL FIRE PRESSURE INT CRIT * SEE NO TEST TYPE FUEL VULN NUMBER FUEL TANK (TYPE) (TYPE) (VEH) (VEH) (TYPE) (TYPE) (VEH) (VEH) (TYPE) (TYPE) (VEH) (VEH)											
TEST	SCRT	PLATE	TEST	SCRT	TEST	SCRT	TEST	SCRT	TEST	SCRT	TEST
NO	TEST	PLATE	NO	TEST	NO	TEST	NO	TEST	NO	TEST	NO
91	2	410	0	60.0	22	90	200	42	.215	0.03	17
91	2	277	21	24	115	74					
92	2	430	40	60.0	22	90	42*	42	.215	0.03	16
92	*	FIRE REIGNITED IN STANDOFF	11	-1	54						
93	2	600	40	60.0	22	91	42*	42	.215	0.03	16
93	2	297	21	14	727	64					
94	2	310	40	60.0	22	70	42*	42	.215	0.03	10
94	2	269	21	8	-1	70					
95	2	400	40	60.0	22	92	95	62*	.215	0.33	30
95	2	257	21	16	-1	17					
96	2	400	40	60.0	22	90	24	42	.215	0.03	10
96	2	269	21	8	-1	70					
97	2	410	40	60.0	22	92	95	62*	.215	0.33	30
97	2	257	21	16	-1	17					
98	2	400	40	60.0	22	90	24	42	.215	0.03	10
98	2	269	21	8	-1	70					
99	2	400	40	60.0	22	90	74*	42	.215	0.03	30
99	2	145	21	8	174	-1					
100	2	400	40	60.0	22	90	16	42	.215	0.03	10
100	2	227	21	24	146	23					
100	*	FIRE REIGNITED IN STANDOFF									

02/16/72	TEST		TYPE		FUEL		TANK		TEMP		TIME		INT		CRIT		SEE				
	NO	TEST	TYPE	FUEL	PHASE	FUEL	TANK	TEMP	TYPE	THICK	SPACE	ANGLE	PROJECTILE	FILL	FIRE	TANK	PRESS	TIME	INT	CRIT	DATA
	NO	TEST	TYPE	FUEL	PHASE	FUEL	TANK	TEMP	TYPE	THICK	SPACE	ANGLE	(TYP OF	VEL)	TYPE	TYPE	PRES	RISE	MAX P	REA I	SHEET
	NO	TEST	TYPE	FUEL	PHASE	FUEL	TANK	TEMP	TYPE	THICK	SPACE	ANGLE	(TYP OF	VEL)	TYPE	TYPE	PRES	RISE	MAX P	REA I	SHEET
91	2	400	A0	40.0	72	90*	12	42	.215	0.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
91	2	391	21	14	76	24						64	0	0	16.0			10.1	10.1	507	
92	2	439	40	40.0	22	90	65*	62	.215	9.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
92	2	375	21	0	47	20						74	0	0	16.0			10.1	10.1	507	
93	2	400	90	40.0	32	90	65*	62	.215	9.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
93	2	192	21	0	156	27						70	0	0	16.0			10.1	10.1	507	
94	2	400	90	40.0	32	90	45*	62	.215	0.03	30	53	2400*	100	1	20.0	0.0	-1.4	3	507	
94	2	142	21	0	127	66						64	0	0	16.0			10.1	10.1	507	
95	2	400	90	40.0	32	90	45*	62	.215	0.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
95	2	211	21	0	209	76						65	0	0	16.0			10.1	10.1	507	
96	2	400	90	40.0	32	90	45*	62	.215	0.03	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
96	2	412	90	40.0	32	90	45*	62	.215	0.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
97	2	210	21	0	46	25						60	0	0	16.0			10.1	10.1	507	
98	2	400	90	40.0	32	90	45*	62	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1.4	3	507	
98	2	412	90	40.0	32	90	45*	62	.215	0.00	30	53	2400*	100	1	20.0	0.0	-1.4	3	507	
99	2	400	90	40.0	32	90	45*	62	.215	0.03	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
99	2	91	21	0	222	70						55	0	0	16.0			10.1	10.1	507	
100	2	214	21	0	40	27	*	*	*	*	*	62	0	0	16.0			10.1	10.1	507	
100	2	400	90	40.0	32	90	45*	62	.215	0.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	
100	2	412	90	40.0	32	90	45*	62	.215	0.00	70	53	2400*	100	1	20.0	0.0	-1.4	3	507	

TEST NO.	TYPE	FUEL	TRAJ	TEMP	STRIKED	PLATE	TYPE	VEL	TANK	SPACE THICK	ANGLE	TYPE	PRESSURE	TANK	PRESSURE	TIME	INT	CRIT	* SEE DATA SHEET	
101	2	400	90	50.0	?	NC	40°	47	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
101	2	100	21	?	30	110	46					94	76	10	10.0		96	152		
102	2	400	90	50.0	?	30	48°	47	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
102	2	200	21	?	35	12	40					54	0	0	10.0		325	507		
103	2	400	90	50.0	?	30	48°	47	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
103	2	252	21	?	30	104	40					65	0	0	10.0		325	507		
104	2	400	90	50.0	?	30	48°	42	.215	9.00	30	53	2400*	100	1	20.0	0.0	-1	4	3
104	2	214	21	?	30	422	46					64	0	0	10.0		325	507		
105	2	400	90	50.0	?	30	48°	42	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
105	2	204	21	?	30	44	42					76	0	0	10.0		325	507		
106	2	600	90	50.0	?	30	40	42	.215	9.00	30	51	2400*	100	1	20.0	-1.0	-1	4	3
106	2	42	21	?	30	42	-1					-1	0	0	10.0		325	507		
107	2	400	90	50.0	?	30	50	47	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
107	2	91	21	?	30	79	27					162	0	0	10.0		325	507		
108	2	400	90	50.0	?	30	50	42	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
108	2	44	21	?	30	126	26					226	0	0	10.0		325	507		
109	2	900	90	50.0	?	30	50	42	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
109	2	78	21	?	30	122	26					216	0	0	10.0		325	507		
110	2	910	90	50.0	?	30	56	42	.215	9.00	30	51	2400*	100	1	20.0	0.0	-1	4	3
110	2	77	21	?	30	125	27					46	0	0	10.0		96	152		



TEST NO. 1511 - FUEL TANK SPILL TEST											
TEST NO.	TYPE	FUEL	VOL.	WEIGHT	TANK TEMP	CANTERATURE	ANGLE	FIRE TYPE	FIRE RISE RATE (FPS)	PRESSURE MAX (PSIA)	TIME INT (SECS)
TEST NO.	SPILL TEST	WT	WT	WT	WT	WT	WT	WT	WT	WT	WT
121	2	112	21	4	44	41			44	4	152
122	2	430	106	40.0	72	90	75	62	0.215	6.37	1
123	2	400	106	40.0	72	90	59	42	0.215	6.03	1
124	2	400	106	40.0	72	90	50	42	0.215	6.03	1
125	2	400	106	40.0	72	90	42	42	0.215	6.03	10
126	2	400	106	40.0	72	90	42	42	0.215	6.03	10
127	2	344	21	6	26	45		42	0.215	6.03	1
128	2	400	106	40.0	72	90	42	42	0.215	6.03	10
129	2	400	106	40.0	72	90	53	42	0.215	6.03	10
130	2	930	166	90.3	22	90	60	42	0.215	6.03	10
131	2	250	21	7	98	-1					3

TEST NO.	TEST TYPE	FUEL VOL	TANK TEMP	TANK PRESSURE	TANK CRIT	TANK DATA	FIRE		FIRE		PRESSURE RISE	MAX P RFA	I	TYPE		(PSIA)		
							CRIT	TIME	CRIT	TIME				CRIT	TIME	(PSI) <sub>1</sub> (SP400)		
131	2	400	106	40.1	107	10	4.0*	4.2	215	4.30	10	53	2400*	100	1	20.0	0.0	-1 4 3
131	2	106	21	0	6	82						73	6	3	16.0	16	152	
132	2	400	106	40.3	107	95	6.0*	6.2	215	6.00	10	53	2400*	100	1	20.0	0.0	-1 4 3
133	2	400	106	40.3	22	90	6.0*	6.2	215	6.03	10	53	2400*	100	1	20.0	0.0	-1 4 3
134	2	40*	21	7	114							64	C	0	16.0	16	152	
134	2	277	71	7	22	117						66	0	0	11.0	56	507	
135	2	400	106	40.0	22	93	6.7	6.7	215	6.93	30	53	2400*	100	1	20.0	0.0	-1 4 3
135	2	375	21	4	-1	77						65	0	0	16.0	56	507	
136	2	400	106	40.0	22	95	6.7	6.7	215	6.10	10	53	2400*	100	1	20.0	0.0	-1 4 3
136	2	400	106	40.0	22	96	6.7	6.7	215	6.07	10	53	2400*	100	1	20.0	0.0	-1 4 3
137	2	400	106	40.1	22	96	6.1	6.2	215	4.33	30	53	2400*	100	1	20.0	0.0	-1 4 3
137	2	270	21	2	-1	67						74	0	0	16.0	56	507	
138	2	400	106	40.0	22	90	6.4	6.2	215	4.90	10	53	2400*	100	1	20.0	0.0	-1 4 3
138	2	275	21	0	60	101						24	0	0	16.0	75	152	
139	2	900	106	40.1	22	96	6.7	6.7	215	6.00	70	53	2400*	100	1	20.0	0.0	-1 4 3
140	2	900	106	40.1	22	96	6.7	6.7	215	6.03	70	53	2400*	100	1	20.0	0.0	-1 4 3
140	2	615	21	11	266	56						74	0	0	16.0	75	152	

TEST NO.	TYPE	FUEL VOL (GAL)	TANK TEMP (°F)	TOAJ	TEMP (°F)	PLATE (STRIKED)	PROJECTILE (THICK TUBE)	FILL TYPE (TYPE I)	FIRE TYPE (TYPE II)	TANK PRESSURE (PSI)	INT (PSI)	CRT (PSI)	FUEL NEPTH (IN)	MAX P REA (PSI)	DATA SHEET	
141	2	400	106	40.0	22	90	50	42	.215	4.13	10	53	2400*	103	1	
141	2	422*	21	1*	254	62					74	0	0	10.0	0.0	-1 4 3
142	2	900	106	40.0	22	90	45	42	.215	4.13	10	53	2400*	100	1	
142	2	431*	21	0	54	69					34	6	0	10.0	0.0	-1 4 3
* STANDOFF FIRE SHOT FLAMES OUT VENT																
143	2	400	106	40.0	22	92	45	42	.215	4.10	10	53	2400*	100	1	
143	2	4570*	21	1*	24	95	95				36	0	0	10.0	0.0	-1 4 3
144	2	400	106	40.0	22	95	57	42	.215	4.00	10	53	2400*	100	1	
144	2	1474	21	1*	24	111					26	0	0	10.0	0.0	-1 4 3
145	2	410	106	40.0	22	90	72	42	.215	4.01	10	53	2400*	100	1	
145	2	3444	21	1*	44	16					116	18	56	10.0	100	507
* FIRE IN STANDOFF - HIGH PRESSURE BRICK VENTILATION EXHAUST TUBE																
146	2	410	106	40.0	22	95	69	42	.215	4.03	10	53	2400*	100	1	
146	2	117*	21	1*	26	55					36	0	0	10.0	0.0	-1 4 3
* TANK PRESSURE BRICK WELD																
147	2	400	106	40.0	22	90	52	42	.215	4.00	10	53	2400*	100	1	
147	2	117*	21	1*	42	20					123	18	51	10.0	100	507
148	2	400	106	40.0	22	90	52	42	.215	4.01	10	53	2400*	100	1	
148	2	124*	21	1*	74	14					120	32	62	10.0	100	507
* FIRE IN STANDOFF WITH FLAMES OUT EXHAUST TUBE AND FLASH OUT STRIKER PLATE																
149	2	400	106	40.0	22	90	54	42	.215	4.01	10	53	2400*	100	1	
149	2	147	21	6	12	112					32	0	0	10.0	0.0	-1 4 3
* STANDOFF FIRE APPEARED OUT BUT REIGNITED AT REAR OF ARTICLE AFTER ENGINE SHUT DOWN - TEST ARTICLE B DAMAGE																
150	2	400	106	40.0	22	94	54	42	.215	4.01	10	53	2400*	100	3	
150	2	-1	21	1*	26	74					144	34	66	10.0	75	152
* EXHAUST TUBE BLOWN OFF AND STANDOFF BURN CAUSED EXTERNAL FIRE BEHIND TEST ARTICLE																

02/16/72											
TEST NO	TYPE	FUEL	TEMP	THERM	VOL	PHASE	FUEL THERM	THERM	TYPE	VEL	ANGLE
	TEST	THERM	THERM	THERM	THERM	THERM	THERM	THERM	THERM	THERM	THERM
151	2	400	106	80.0	22	g0	69	62	215	4.01	30
151	2	74.9	21	12	92	113					
152	2	400	106	80.0	22	g0	60	62	215	4.01	30
152	2	211	21	a	100	aa					
153	2	400	106	80.0	22	g0	59	62	215	4.00	30
153	2	29.4	21	a	144	76					
154	2	400	106	80.0	22	g0	70	42	215	4.11	30
154	2	-1	21	a	14	q1					
155	2	400	40	60.0	22	75	40*	42	215	9.01	30
155	2	-1	21	a	14	q1					
156	2	400	40	60.0	22	75	70*	42	215	9.01	30
156	2	-1	21	a	14	q1					
157	2	400	40	60.0	22	q0	90*	42	215	9.01	30
157	2	201	21	a	214	64					
158	2	400	40	60.0	22	75	70*	42	215	9.01	30
158	2	212	21	a	-1	q1					
159	2	400	40	60.0	22	q0	74*	42	215	9.00	30
159	2	225	21	a	204	27					
160	2	470	40	60.1	22	90	40*	42	215	9.01	30
160	2	472	21	a	211	14					

TEST TYPE FUEL TANK										TEST TYPE FUEL TANK									
NO	TEST	TYPE	VOL	WHT	SPCE	THRN	SPCE	AVGFL	YELF	FILL	FRPF	TANK	PRESS	TIME	INT	CRIT	* SEE		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)		
161	2	630	90	40.3	27	23	AC*	62	0.215	0.31	53	240C*	100	1	15.0	.7	-1 4 3		
161	2	454+	21	10	74.2	31				64	0	3	14.0		23	152			
162	2	401	40	60.1	22	20	49*	62	0.215	0.30	53	240C*	100	1	15.0	.4	-1 4 3		
162	2	441+	21	10	71.6	20				52	0	0	14.0		23	152			
163	2	907	90	40.0	27	26	70	42	0.215	0.03	53	240C*	100	1	20.0	0.0	-1 1 3		
163	2	-1	21	11	47.6	37				24	0	0	14.0		23	152			
164	2	900	90	61.0	22	74	70	42	0.215	0.01	53	240C*	100	1	20.0	0.0	-1 4 3		
164	2	119	21	7	11.6	40				43	0	0	14.0		23	152			
* FIRE IN STANDOFF - SECOND PRESSURE AND TEMPERATURE RISE OCCURRED AT 1.5 SECONDS																			
165	2	910	90	60.0	22	75	72	42	0.215	0.00	53	240C*	100	1	20.0	0.0	-1 4 3		
165	2	415	21	6	5.5	41				64	0	0	16.0		23	152			
* FIRE IN STANDOFF - SECOND PRESSURE AND TEMPERATURE RISE OCCURRED AT 2.7 SECONDS																			
166	2	401	40	60.0	27	23	42	0.215	0.21	53	240C*	100	1	15.0	1.7	-1 3 4 3			
166	2	457+	21	10	71	47				64	0	0	16.0		23	152			
* LARGE CLOUD OF SMOKE AND FLAMES SHOT OUT VENT TUBE																			
167	2	910	90	40.0	27	40	72	42	0.215	0.013	53	240C*	100	1	15.0	1.6	-1 0 4 3		
167	2	478+	21	4	67.6	47				75	0	3	16.0		23	152			
168	2	910	90	60.1	22	01	72	42	0.215	0.01	53	240C*	100	1	15.0	2.1	-1 6 2 3		
168	2	0	21	0	-1	41				44	0	0	14.0		23	152			
169	2	400	90	60.1	27	75	77	42	0.215	0.03	53	240C*	100	1	20.0	1.3	-1 8 4 3		
169	2	256	+21	12	36.6	48				70	0	0	14.0		23	152			
* FIRE IN STANDOFF AND OUT EXHAUST TUBE																			
170	2	910	90	60.1	27	75	77	42	0.215	0.33	53	240C*	100	2	20.0	2.4	-1 9 4 3		
170	*	294	+21	11	24.6	54				63	0	0	14.0		23	152			



TEST 1577 - FUEL TANK FUEL TYPE: FUEL PHASE: LIQUID FUEL VOLUME: 100.0 (GAL)										TEST 1578 - FUEL TANK FUEL TYPE: FUEL PHASE: LIQUID FUEL VOLUME: 100.0 (GAL)									
TEST	SPC	CRT	STANDOFF	TEST	SPC	CRT	STANDOFF	TEST	SPC	CRT	STANDOFF	TEST	SPC	CRT	STANDOFF	TEST	SPC	CRT	STANDOFF
142	2	21	-1	40	-1	-1	-1	45	0	0	0	140	0	0	0	140	0	0	0
143	2	21	-1	41	146	-1	-1	46	0	0	0	140	0	0	0	140	0	0	0
144	2	21	-1	42	147	-1	-1	47	0	0	0	140	0	0	0	140	0	0	0
145	2	21	-1	43	148	-1	-1	48	0	0	0	140	0	0	0	140	0	0	0
146	2	21	-1	44	149	-1	-1	49	0	0	0	140	0	0	0	140	0	0	0
147	2	21	-1	45	150	-1	-1	50	0	0	0	140	0	0	0	140	0	0	0
148	2	21	-1	46	151	-1	-1	51	0	0	0	140	0	0	0	140	0	0	0
149	2	21	-1	47	152	-1	-1	52	0	0	0	140	0	0	0	140	0	0	0
150	2	21	-1	48	153	-1	-1	53	0	0	0	140	0	0	0	140	0	0	0
151	2	21	-1	49	154	-1	-1	54	0	0	0	140	0	0	0	140	0	0	0
152	2	21	-1	50	155	-1	-1	55	0	0	0	140	0	0	0	140	0	0	0
153	2	21	-1	51	156	-1	-1	56	0	0	0	140	0	0	0	140	0	0	0
154	2	21	-1	52	157	-1	-1	57	0	0	0	140	0	0	0	140	0	0	0
155	2	21	-1	53	158	-1	-1	58	0	0	0	140	0	0	0	140	0	0	0
156	2	21	-1	54	159	-1	-1	59	0	0	0	140	0	0	0	140	0	0	0
157	2	21	-1	55	160	-1	-1	60	0	0	0	140	0	0	0	140	0	0	0
158	2	21	-1	56	161	-1	-1	61	0	0	0	140	0	0	0	140	0	0	0
159	2	21	-1	57	162	-1	-1	62	0	0	0	140	0	0	0	140	0	0	0
160	2	21	-1	58	163	-1	-1	63	0	0	0	140	0	0	0	140	0	0	0
161	2	21	-1	59	164	-1	-1	64	0	0	0	140	0	0	0	140	0	0	0
162	2	21	-1	60	165	-1	-1	65	0	0	0	140	0	0	0	140	0	0	0
163	2	21	-1	61	166	-1	-1	66	0	0	0	140	0	0	0	140	0	0	0
164	2	21	-1	62	167	-1	-1	67	0	0	0	140	0	0	0	140	0	0	0
165	2	21	-1	63	168	-1	-1	68	0	0	0	140	0	0	0	140	0	0	0
166	2	21	-1	64	169	-1	-1	69	0	0	0	140	0	0	0	140	0	0	0
167	2	21	-1	65	170	-1	-1	70	0	0	0	140	0	0	0	140	0	0	0
168	2	21	-1	66	171	-1	-1	71	0	0	0	140	0	0	0	140	0	0	0
169	2	21	-1	67	172	-1	-1	72	0	0	0	140	0	0	0	140	0	0	0
170	2	21	-1	68	173	-1	-1	73	0	0	0	140	0	0	0	140	0	0	0
171	2	21	-1	69	174	-1	-1	74	0	0	0	140	0	0	0	140	0	0	0
172	2	21	-1	70	175	-1	-1	75	0	0	0	140	0	0	0	140	0	0	0
173	2	21	-1	71	176	-1	-1	76	0	0	0	140	0	0	0	140	0	0	0
174	2	21	-1	72	177	-1	-1	77	0	0	0	140	0	0	0	140	0	0	0
175	2	21	-1	73	178	-1	-1	78	0	0	0	140	0	0	0	140	0	0	0
176	2	21	-1	74	179	-1	-1	79	0	0	0	140	0	0	0	140	0	0	0
177	2	21	-1	75	180	-1	-1	80	0	0	0	140	0	0	0	140	0	0	0
178	2	21	-1	76	181	-1	-1	81	0	0	0	140	0	0	0	140	0	0	0
179	2	21	-1	77	182	-1	-1	82	0	0	0	140	0	0	0	140	0	0	0
180	2	21	-1	78	183	-1	-1	83	0	0	0	140	0	0	0	140	0	0	0
181	2	21	-1	79	184	-1	-1	84	0	0	0	140	0	0	0	140	0	0	0
182	2	21	-1	80	185	-1	-1	85	0	0	0	140	0	0	0	140	0	0	0
183	2	21	-1	81	186	-1	-1	86	0	0	0	140	0	0	0	140	0	0	0
184	2	21	-1	82	187	-1	-1	87	0	0	0	140	0	0	0	140	0	0	0
185	2	21	-1	83	188	-1	-1	88	0	0	0	140	0	0	0	140	0	0	0
186	2	21	-1	84	189	-1	-1	89	0	0	0	140	0	0	0	140	0	0	0
187	2	21	-1	85	190	-1	-1	90	0	0	0	140	0	0	0	140	0	0	0
188	2	21	-1	86	191	-1	-1	91	0	0	0	140	0	0	0	140	0	0	0
189	2	21	-1	87	192	-1	-1	92	0	0	0	140	0	0	0	140	0	0	0
190	2	21	-1	88	193	-1	-1	93	0	0	0	140	0	0	0	140	0	0	0
191	2	21	-1	89	194	-1	-1	94	0	0	0	140	0	0	0	140	0	0	0
192	2	21	-1	90	195	-1	-1	95	0	0	0	140	0	0	0	140	0	0	0
193	2	21	-1	91	196	-1	-1	96	0	0	0	140	0	0	0	140	0	0	0
194	2	21	-1	92	197	-1	-1	97	0	0	0	140	0	0	0	140	0	0	0
195	2	21	-1	93	198	-1	-1	98	0	0	0	140	0	0	0	140	0	0	0
196	2	21	-1	94	199	-1	-1	99	0	0	0	140	0	0	0	140	0	0	0
197	2	21	-1	95	200	-1	-1	100	0	0	0	140	0	0	0	140	0	0	0
198	2	21	-1	96	201	-1	-1	101	0	0	0	140	0	0	0	140	0	0	0
199	2	21	-1	97	202	-1	-1	102	0	0	0	140	0	0	0	140	0	0	0
200	2	21	-1	98	203	-1	-1	103	0	0	0	140	0	0	0	140	0	0	0
201	2	21	-1	99	204	-1	-1	104	0	0	0	140	0	0	0	140	0	0	0
202	2	21	-1	100	205	-1	-1	105	0	0	0	140	0	0	0	140	0	0	0
203	2	21	-1	101	206	-1	-1	106	0	0	0	140	0	0	0	140	0	0	0
204	2	21	-1	102	207	-1	-1	107	0	0	0	140	0	0	0	140	0	0	0
205	2	21	-1	103	208	-1	-1	108	0	0	0	140	0	0	0	140	0	0	0
206	2	21	-1	104	209	-1	-1	109	0	0	0	140	0	0	0	140	0	0	0
207	2	21	-1	105	210	-1	-1	110	0	0	0	140	0	0	0	140	0	0	0
208	2	21	-1	106	211	-1	-1	111	0	0	0	140	0	0	0	140	0	0	0
209	2	21	-1	107	212	-1	-1	112	0	0	0	140	0	0	0	140	0	0	0
210	2	21	-1	108	213	-1	-1	113	0	0	0	140	0	0	0	140	0	0	0
211	2	21	-1	109	214	-1	-1	114	0	0	0	140	0	0	0	140	0	0	0
212	2	21	-1	110	215	-1	-1	115	0	0	0	140	0	0	0	140	0	0	0
213	2	21	-1	111	216	-1	-1	116	0	0	0	140	0	0	0	140	0	0	0
214	2	21	-1	112	217	-1	-1	117	0	0	0	140	0	0	0	140	0	0	0
215	2	21	-1	113	218	-1	-1	118	0	0	0	140	0	0	0	140	0	0	0
216	2	21	-1	114	219	-1	-1	119	0	0	0	140	0	0	0	140	0	0	0
217	2	21	-1	115	220	-1	-1	120	0	0	0	140	0	0	0	140	0</td		



TEST TYPE FUEL TANK TEST (SHEET 1 OF 10)											
TEST	SPCC	CRT	WLT	VUL	VUL	SPCR	SPCR	PLATE	(PROJECTILE) FILL	F12F	TANK PRESSURE
NO TEST	2	430	41	40.0	27	30	37	42	+125 0.03	0	53 2400psi 100 2 15.0 2.3 11.2 6
203	2	3	31	1	3	-1					0 15.0 0 0 15.2
204	2	430	41	40.0	27	31	42	42	+125 0.03	0	53 2400psi 100 2 15.0 2.6 11.2 6
204	2	0	31	1	0	-1					0 15.0 0 0 15.2
205	2	430	41	40.0	32	30	42	42	+125 0.03	0	53 2400psi 100 1 15.0 2.6 11.2 6
205	2	1	31	1	0	-1					0 15.0 0 0 15.2
206	2	430	41	40.1	32	30	42	42	+125 0.03	0	53 2400psi 100 1 15.0 2.7 11.2 6
206	2	0	21	0	0	-1					0 15.0 0 0 15.2
207	2	430	41	40.1	32	30	42	42	+125 0.03	0	53 2400psi 100 1 15.0 3.5 11.2 6
207	2	0	21	0	0	-1					0 15.0 0 0 15.2
208	2	430	41	40.1	32	30	74	42	+125 0.03	0	53 2400psi 100 1 15.0 2.3 10.2 6
209	2	430	41	40.1	32	30	74	42	+125 0.03	0	53 2400psi 100 1 15.0 2.2 10.2 6
209	2	0	21	1	0	-1					0 15.0 0 0 15.2
210	2	430	41	40.0	32	33	61	42	+125 0.03	0	53 2400psi 100 2 15.0 1.3 11.2 6
210	2	1	21	1	0	-1					0 15.0 0 0 15.2
211	2	430	41	40.0	32	33	61	42	+125 0.03	0	53 2400psi 100 1 15.0 2.6 10.2 6
211	2	0	21	1	0	-1					0 15.0 0 0 15.2
212	2	430	41	40.0	32	30	61	42	+125 0.03	0	53 2400psi 100 1 15.0 1.2 11.2 6
212	2	1	21	0	0	-1					0 15.0 0 0 15.2









AFAPL-TR-72-83

APPENDIX II

POSSIBLE CONTAMINATION OF JP-8  
TEST BY PREVIOUS JP-4 TEST

Although it was standard procedure to completely wash the test article with water between tests to remove all fuel and fuel vapor, it was of concern that the first shot in a JP-8 test series may in some way be contaminated by the previous JP-4 test series. To investigate this possibility, the standoff pressure rise of several "first shots" of a JP-8 series which were preceded by a JP-4 shot was compared to the standoff pressure rise of the "last shots" of the several JP-8 series of interest. The results of the analysis is shown by Table XIII. Since no significance is shown, we concluded that the JP-8 tests were not contaminated by previous JP-4 tests and the water wash was sufficient.

TABLE XIII  
MAXIMUM STANDOFF PRESSURE OF  
FIRST VERSUS LAST JP-8 SHOT OF A SERIES

First Test		Last Test	
Test No.	Pressure Rise (psi X 10)	Test No.	Pressure Rise (psi X 10)
13	167	18	27
25	87	30	113
43	44	48	76
64	38	68	6
80	40	85	58
128	32	133	48
163	32	168	48
Variance	2515		1181
Mean	62		54
F Ratio - 2.1	T Value - 0.43	T <sub>c</sub> - 1.78	

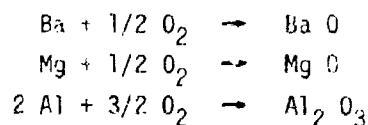
APPENDIX III  
OXYGEN DILUTION DUE TO INCENDIARY FUNCTIONING

The projectile velocity, impact angle, and strike plate thickness were determined by tests to provide maximum functioning in the dry bay of the incendiary mix associated with the CAL .50 API. This was done to provide the "biggest match" possible for fuel ignition in the dry bay. Since the incendiary is fuel rich, some oxygen in the dry bay may enter into the reaction. In addition, the products of the reaction may tend to dilute the oxygen concentration. If the oxygen concentration is reduced to below 12% by volume, no fuel reaction can be expected (Reference 4). The following analysis addresses these questions as a first approximation, and the results are presented in Figure 13. As may be seen in this figure, all the test articles and associated dry bays used in this program should have had sufficient oxygen to support a fuel reaction. This figure gives minimum values of  $O_2$  remaining, and since only a small part of the incendiary reacts in the dry bay, the results are conservative. The following calculations were used to develop Figure 13.

The incendiary mix, IM-11, of the CAL .50 API weights 1.0 gram and has the following composition:

50% by weight  $Ba(NO_3)_2$   
25% by weight Mg  
25% by weight Al

For complete combustion of the incendiary mix the following reaction must be considered:



Gram Moles initially present in 1.0 gm of incendiary

$$\frac{.5 \text{ gms. Ba (NO}_3)_2}{261.3 \text{ gms./gm. mole Ba (NO}_3)_2} = 1.92 \times 10^{-3} \text{ gm moles Ba (NO}_3)_2$$

$$\frac{.25 \text{ gms. Mg}}{24.3 \text{ gms./gm. mole Mg}} = 1.027 \times 10^{-2} \text{ gm moles Mg}$$

$$\frac{.25 \text{ gms. Al}}{26.98 \text{ gms./gm mole Al}} = 0.927 \times 10^{-2} \text{ gm moles Al}$$

gm moles O<sub>2</sub> present in 0.5 gm of Ba (NO<sub>3</sub>)<sub>2</sub>

$$\frac{3 \text{ moles O}_2}{1 \text{ mole Ba (NO}_3)_2} \times 1.92 \times 10^{-3} \text{ gm moles Ba (NO}_3)_2 = 5.76 \times 10^{-3} \text{ gm moles O}_2$$

gm moles N<sub>2</sub> present in 0.5 gm of Ba (NO<sub>3</sub>)<sub>2</sub>

$$\frac{1 \text{ mole N}_2}{1 \text{ mole Ba (NO}_3)_2} \times 1.92 \times 10^{-3} \text{ gm moles Ba (NO}_3)_2 = 1.92 \times 10^{-3} \text{ gm moles N}_2$$

Total gm moles O<sub>2</sub> required for complete reaction

Ba requires .00096	gm moles O <sub>2</sub>
Mg requires .00513	gm moles O <sub>2</sub>
Al requires .00695	gm moles O <sub>2</sub>
.01304 Total gm moles O <sub>2</sub> required	

Total gm moles of additional  $O_2$  required from the air

$$\begin{array}{l} .01304 \text{ total gm moles } O_2 \text{ required} \\ -.00576 \text{ gm moles } O_2 \text{ existing in mix} \\ .00728 \text{ additional gm moles } O_2 \text{ required} \end{array}$$

Vol. of  $O_2$  needed from air at  $25^\circ C$  per 1 gm incendiary

$$V_{O_2} = \frac{nRT}{P}$$

$$V_{O_2} = (.00728 \text{ gm moles } O_2 \text{ required})$$

$$\left( \frac{.08205 \text{ atm - liter}}{\text{gm mole - } ^\circ\text{K}} \right) \left( \frac{.0353 \text{ ft}^3}{\text{liter}} \right) \left( \frac{296^\circ\text{K}}{1 \text{ atm}} \right)$$

$$V_{O_2} = 6.28 \times 10^{-3} \text{ ft}^3 \text{ needed from air}$$

Vol. of  $N_2$  released during reaction at  $2000^\circ K$

$$V_{N_2} = (.00192 \text{ gm moles } N_2 \text{ released})$$

$$\left( \frac{.08205 \text{ atm - liter}}{\text{gm mole - } ^\circ\text{K}} \right) \left( \frac{2000^\circ\text{K}}{(1 \text{ atm})} \right) \left( \frac{.0353 \text{ ft}^3}{\text{liter}} \right)$$

$$V_{N_2} = .0111 \text{ ft}^3 N_2 \text{ released}$$

Since the following oxides will be solids they will not dilute the dry bay oxygen:

$Al_2 O_3$  Boiling Point =  $3500^\circ C$

$Ba O$  Boiling Point =  $2000^\circ C$

$Mg O$  Melting Point =  $2800^\circ C$

Now let  $V_R$  = the final  $O_2$  volume % in the dry bay -  $\text{ft}^3$

$V_D$  = Volume of the dry bay -  $\text{ft}^3$

$$V_R = \frac{.21 V_D (\text{initial } O_2 \text{ vol.}) - .00628 \text{ ft}^3 (O_2 \text{ needed from air}) \times 100\%}{V_D - .00628 \text{ ft}^3 (O_2 \text{ needed from air}) + .0111 \text{ ft}^3 (N_2 \text{ released})}$$

$V_R = \frac{.21 V_D - .628}{V_D + .00482}$	This equation was used to develop Figure 13.
---	--

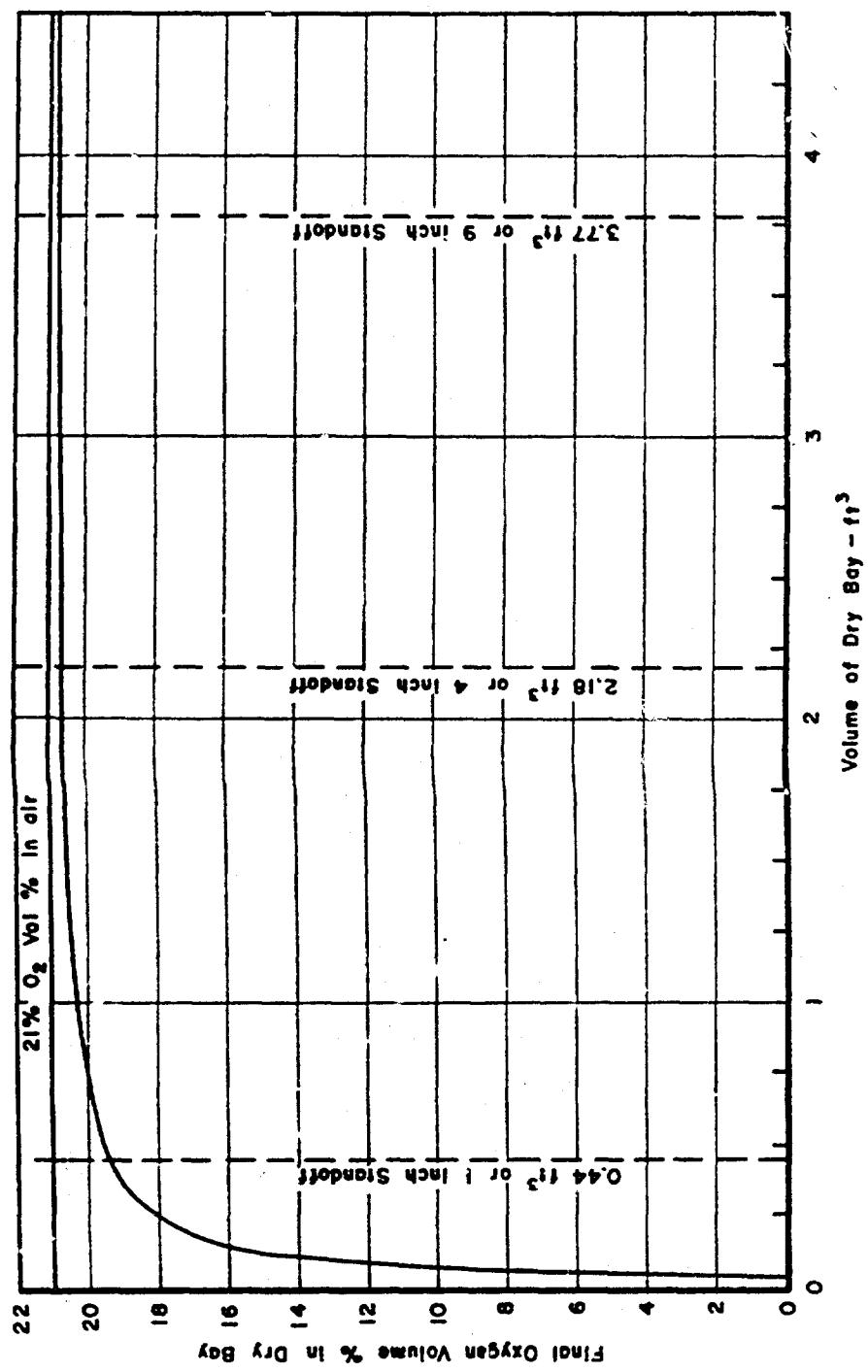


Figure 13. Final Oxygen Volume Percent in Dry Bay After Incendiary Reaction

APPENDIX IV  
SAMPLE STATISTICAL PROBLEM

We generated a sample set of data to obtain some insight into the results that could be expected from the use of statistical methods. Twelve random numbers (A in Table XIV) were selected, ranging from 0 to 35, which was the expected range of overpressure for the standoff volume. The numbers for comparison were defined as  $B = 0.6A$ . Therefore, by definition, the difference between any set of A and B numbers was 40%. It was then assumed four tests were conducted giving the first two responses of both A and B. A statistical analysis was performed on the results. This was repeated assuming eight additional tests. In the final step it was assumed that twelve more tests were conducted. The statistical results for the sample problem are given in Table XIV. As may be seen, the defined difference between A and B was not shown in the calculated T value until all 24 tests were conducted.

Another sample problem was also conducted (results not shown) with the same values of A but with  $B = 0.8A$ . The same procedure was applied, and even after 24 tests the T value did not show the defined 20% difference between A and B as significant.

The foregoing example was generated to illustrate that it is difficult to prove with high confidence a difference between two fuels if that difference is relatively small and only a limited number of tests are conducted; the smaller the difference, the more tests are required to prove a significant difference.

TABLE XIV  
SAMPLE STATISTICAL PROBLEM (RANDOM NUMBERS 0 TO 35)  
 $B = 0.6A$  (BY DEFINITION)

No.	Test Description		Variance		Mean		F Ratio	$T_c$ Value	Remarks	
	A	B	A	B	A	B				
1	34.0	20.4	200.0	72.0	24.0	14.4	2.78	1.43	2.92 Based on 4 tests	
	14.0	8.4								
2	11.0	6.6	10.8	2.0	1.2	44.4	8.6	2.78	1.81 Based on 12 tests	
	18.0	1.2								
3	7.0	4.2	123.5	44.4	14.3	8.6	2.78	1.28	1.81 Based on 24 tests	
	17.0	10.2								
	19.0	11.4	1.0	0.6	30.0	18.0	11.0	6.6	1.72 Based on 24 tests	
	1.0	0.6								
	30.0	18.0	11.0	7.2	12.0	98.6	35.5	14.7	1.91	1.72 Based on 24 tests
	11.0	6.6								

APPENDIX V  
PROPERTIES OF JP-4 AND JP-8 FUELS

At the present time the United States Air Force uses JP-4 (Commercial Designation: JET B), a wide-cut distillate fuel, as its preferred operational fuel. JP-4 was adopted back in the early 1950's, and its properties were selected to maximize worldwide availability while fulfilling aircraft operational performance requirements. The proposed replacement fuel, JP-8, has lower volatility, and its properties were determined by worldwide availability, operational performance, and fire safety considerations. The comparative properties of JP-4 and JP-8 are given in Table XV.

TABLE X  
PROPERTIES OF JP-4 AND JP-8 FUELS

	JP-4*	JP-8*	JP-4 SPEC.	JP-8 SPEC.	PROPOSED JP-8 SPEC.
Flash Point (°F)	-20	118	----	----	105-150
Distillation (°F)					
(a) Initial Boiling Point	140	314	----	----	----
(b) End Point	455	508	----	----	550
*Gravity (°API)	54.4	43.8	----	----	39-51
Freeze Point (°F)	-80	-65	-76 max.	-54 max.	----
Aromatics	11.4	16	25 max.	25 max.	----
Clefins	1	2	----	5 max.	----
Viscosity (Centistokes at - 30°F)	2.4	8	----	15 max.	----
Reid Vapor pressure (psi at 100°F)	2.6	<0.1	2.0-3.0	----	----
Density (lbs/gal)	6.41	6.81	6.25-6.69	6.46-6.91	----
Heat of Combustion					
(a) BTU/lb	18,714	18,559	18,400 min.	18,400 min.	----
(b) BTU/gal	119,557	125,830	----	----	----
Autoignition Temp. (°F)	~484 min.	~473	----	----	----
Burning Velocity- Vapor-Air Mixture (ft/sec)	~1-2	~1-2	----	----	----
Flame Spread Rate, Quiescent Liquid, 80°F (ft/min)	~750	~25	----	----	----

\* TYPICAL OF FUEL USED IN FAA TEST PROGRAM

REFERENCES

1. G. W. Gandee "Evaluation of Fire Safe Fuels," paper presented at the Industry-Military Jet Fuel Quality Symposium, October 22, 23, and 24, 1968, San Antonio, Texas.
2. AFAPL-TR-70-93, AFAPL Aircraft Fire Test Program with FAA, 1967-1970, June 1971.
3. APFH-TM-70-34, "Evaluation of JP-8 Versus JP-4 Fuel for Enhancement of Aircraft Combat Survivability," June 1970.
4. AFAPL-TR-70-82, Influence of Fuel Slosh Upon the Effectiveness of Nitrogen Inerting for Aircraft Fuel Tank, February 1971.